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PHILIPPINE WEATHER BUREAU,
MANILA OBSERVATORY.

Febr 2nd 1905.

P. T.

Acting under the authority of the Honorable the Secretary of the Interior, Philippine Government, the Philippine Weather Bureau has the pleasure of transmitting to you a copy of the Special Report of the Director, entitled "The Cyclones of the Far East."

As the copies of this publication must be accounted for it is most respectfully suggested that you sign the adjoined receipt and return the same to the Philippine Weather Bureau Manila, P. I.

Very respectfully,

JOSÉ ALGUÉ.

DEPARTMENT OF THE INTERIOR.

WEATHER BUREAU.

SPECIAL REPORT OF THE DIRECTOR OF THE PHILIPPINE WEATHER BUREAU.

THE CYCLONES OF THE FAR EAST

BY

REV. JOSÉ ALGUÉ, S. J.,

DIRECTOR OF THE PHILIPPINE WEATHER BUREAU,

MANILA OBSERVATORY.

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PREFACE.

In the preface to the first edition, 1897, I said: "This book was written as an essay in order not to deprive the public longer of the practical utility which may be derived from a study of the data concerning typhoons which have been gathered in this observatory from its foundation in 1865 to the present. In view of the immense amount of valuable material I should believe myself wanting in my duty if I did not at once make use of these treasures for the benefit of those who navigate these tempestuous seas and of the inhabitants of these Islands, so beautiful, but subject to the disastrous typhoons.

"Though there have been difficulties to discourage me in the undertaking, still, taking all into consideration, I think that those very reasons may serve as an excuse for the defects in my attempt. For it is clear that the roar of cannon and the rumors of war rob the mind of that calmness which is so necessary in a work of this kind. This is especially so when the anxieties of my charge are multiplied in an observatory dedicated to the study of the cyclonic storms where duty keeps the mind in a state of continual watchfulness and where there is an obligation of satisfying the just demands of inquirers for the saving of life and property. All these motives seem to me sufficient to merit for me the indulgence of my readers.

"Having finished with the help of God this small work, we offer it to the public under the title of 'Baguios or Cyclones of the Philippines,' or, as we might also say, 'Baguios, Typhoons, or Cyclones of the Philippines,' for in reality the storms which the natives of these Islands call baguios are nothing more than the tropical cyclonic storms or simply cyclones of the same nature as the hurricanes of the Antilles and the cyclones of the Atlantic, and identical with the typhoons of the China Sea; for there is no tropical storm which is developed or felt in the sea or on the coasts of China which has not exercised some influence upon this Archipelago."

"We divide the book into three parts. In the first we give some idea of the nature of the typhoon, of its origin, its structure, and of its internal and external movements, which constitute the laws of cyclonic circulation and of the progressive motion. This part forms what we call the theory.

"In the second part we treat of the phenomena which generally precede these terrible storms, so as to enable the observer to predict, as far as this is possible, their effects; for which purpose we give some practical rules.

"The third part contains the confirmatory evidence for the first and second. In it we give instances of the different types and classes of typhoons for the purpose of analyzing their real character and of deducing some general properties. We also point out some of the anomalies which may occur. The third and second parts are, therefore, essentially practical and thus the combination of the three constitutes a theoretico-practical study of typhoons."

Since the first edition appeared in 1897 abundant additional data have been collected, not only from the Philippines themselves but also from the surrounding coasts, and these have been embodied in the present edition. Owing to the opening up of the Far East in recent years, an endeavor has been made to extend the usefulness of the work by giving a greater compass to the study of the phenomena which cause, accompany, and follow the atmospheric perturbances which are experienced in the various seas of the Far East. These additions and the different arrangement of the book seem to justify the designation of this as a "revised" edition, and it is confidently hoped that it also will be found not only an enlarged but also greatly improved reissue of the book. Owing to the greater scope of the book we change the title from "Cyclones of the Philippines" to "The Cyclones of the Far East."

The first edition having been in Spanish, this appears in English, both for the fact that it emanates from a department organized under the Government of the Philippine Islands and in order to make the fruits of our labors accessible to as many seafaring men as possible.

There is indeed an English version of the first edition in existence; but owing to the fact that it is a translation of a translation, that is, of the German translation of our work made by Prof. Dr. Paul Bergholz and published by him under the title of "Die Orkane des Fernen Ostens, von Prof. Dr. Paul Bergholz (1900)"—it contains numerous scientific inaccuracies (to express it mildly), while a number of passages are sheer nonsense. We make this statement with due respect for the eminent meteorologist whose name figures on the title page of "The Hurricanes of the Far East, by Prof. Dr. Paul Bergholz; English translation revised by Dr. Robert H. Scott, F. R. S.," as reviser. As stated in a letter to the editor of Nature (Nature, March 19, 1903, p. 469), Dr. Scott confined himself "to correct the German idioms in the sheets sent" to him—though even in this regard he has gone to the very limit of leniency—evidently supposing that the translation was correct as to scientific statements.

In justice to Dr. Bergholz we must add that of a formidable list of errors, etc., found in the English version but few occur in the German edition, the rest being thus demonstrated as due to the ignorance of the person who rendered Dr. Bergholz's translation in English.

Moreover, these translations give in many chapters only an extract of the original.

Of the many additions contained in this new edition the following are the more important:

(1) A fourth part, which deals with some practical rules for navigating in case of encountering a typhoon, and also gives a list and descriptions of the ports of refuge during storms in the Far East, especially in the Philippine Archipelago.

(2) A new classification of the cyclones of the Far East.

(3) A study of the frequency, absolute and relative to certain districts and months, of cyclones.

(4) A new, more exhaustive description and discussion of the barocyclonometer and its use, with many practical instances illustrating its application.

(5) The relation between some microseismic movements and the progress of cyclones.

(6) Some remarkable barometric minima during cyclones.

(7) A new type of cyclones which raged in the Gulf of Bengal after having affected or crossed the Philippine Archipelago.

(8) The relation between the average motion of the higher clouds in the Northern Hemisphere and the general tracks of cyclones.

Other additions of minor importance will be found in nearly every chapter.

I tender my most sincere thanks to the Rev. Robert Brown, S. J., who has been of great assistance in preparing this English edition. Thanks are also due to the Rev. George M. Zwack, S. J., to whose laborious and careful work in revising the whole book and in comparing the German and English translations of the first edition with each other and with the Spanish original and in pointing out the scientific inaccuracies found in them, I am greatly indebted.

José Algué, S. J.

Manila Observatory, *December 3, 1903.*

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PART I. THE CYCLONES.

PART I. THE CYCLONES.

CHAPTER I. ELEMENTS OF A CYCLONE.

GENERAL DEFINITIONS.

Cyclone, baguio, or typhoon.[1]—Baguio or typhoon is a vast whirl of aerial currents which surround a central space of calm, relatively small, called the "vortex" or "center" of the storm.

Cyclonic movement, and the movement of translation.—Two classes of movements must be distinguished in typhoons—that of rotation, commonly called cyclonic circulation, which has proved itself in our hemisphere to be from right to left (that is, from east, through north, west, and south); and that of translation, which translates the typhoon from its site of origin to other regions along a path called its "trajectory," or the track of the cyclone.

Anterior semicircle, posterior semicircle.—In order to better understand what we have to say in this and the following chapters, we have divided the typhoon into different regions. Plate I gives a horizontal section of a typhoon. The arrow A′ and B′ indicates the direction of the storm's path. Of the two semicircles formed by a perpendicular (in the plane of the horizon) to the trajectory we call the one that lies on the side toward which the storm is moving the anterior part of the typhoon; the other, the posterior part. These two semicircles are sometimes known as the advancing and retreating semicircles, respectively. The right part of the typhoon is that semicircle formed by the prolongation of trajectory which lies to the right of an observer looking in the direction in which the center advances, while the other semicircle comprises the left part.

Safe semicircle; dangerous semicircle.—The right-hand semicircle is called by some meteorologists unmanageable, or dangerous, and the left-hand one manageable, or safe; doubtless because in the former the translatory motion of the vortex causes the greater component of the wind to be felt, while in the latter the contrary takes place, as is easily seen by looking at Plate I. Several celebrated meteorologists do not admit the existence of such semicircles. They always divide the typhoon into four quadrants; the first quadrant lies at the front to the right, the second at the rear to the right, the third at the rear to the left, and the fourth at the front to the left.

Form of the cyclone.—In Plate I is given a horizontal section of the body of a cyclone, as circular, in order to understand better the constituent parts of the meteor. It but seldom takes this form; the nucleus is generally irregular, chiefly elliptical, and the whole cyclone usually takes the form of the center. The irregularity and diversity of form is due in a great measure to the topographical conditions of the track of the storm and to the speed of the progressive motion, as well as to the position of the major axis relative to the trajectory, when the form of the center is elliptical.

---

[1] Several words are used to denote the tropical cyclones—typhoon, baguio, and hurricane. The word "typhoon," according to Hirth, comes from Tai-fung; "tai" being a word which used to be employed in Formosa to signify a strong, veering wind; "fung," an old Chinese word, meaning simply wind. We leave to philologists to solve the question whether the "ventus typhonicus" of Chapter XXVII of the Acts of the Apostles, verse 14, was a real circulatory cyclone or not. The Greeks seemed to call a strong wind a "typhoon." For confirmation of this we refer the reader to Pliny "de repentinis flatibus," book 2, Chapter XLVIII, and to Aristotle "Meteor." book 3. It may be that the word comes from the Greek τυφω, to burn.

For the difference in meaning between cyclone, hurricane, and tornado see Monthly Weather Review, July, 1899, page 307.

For the pronunciation of the word "baguio," see a note by Prof. Dean Worcester in Monthly Weather Review, October, 1899, page 470.

Center or vortex.—It is necessary to distinguish two classes of centers in typhoons—the center of the storm itself, that is to say, the point or region about which a system of winds is revolving, and the barometrical center of the cyclone, that is to say, the center of the small circle or isobaric ellipse, which confines the central area. This latter is called the center in modern dynamic meteorology, while the former is the center of mariners and ancient meteorologists and is generally spoken of as the vortex or center of the cyclone, especially since the direction of the winds tends to point out its bearings and baric gradient.

Isobars and barometric gradient.—From what has been said in the preceding paragraph it is clear that the distribution of isobars—that is to say, of the lines which unite points of equal pressure around the center—is not regular and symmetrical, but generally irregular, accommodating itself to the shape of the vortex. We call the difference of atmospheric pressure measured on a line perpendicular to the isobar the barometric gradient or pressure slope. The magnitude of the gradient is expressed by the number of millimeters or of hundredths of an inch which the pressure diminishes or increases along the said perpendicular for each geographical mile of distance or for some other distance chosen as a unit. The units now selected and used by international agreement are, respectively, one-one-hundredth of an inch of pressure and 15 geographical miles, that is, one-fourth of an equatorial degree. By means of the amount and direction of the gradient, we are able to determine the distribution of atmospheric pressure around the vortex. According to the general opinion of meteorologists, the magnitude of the barometric gradient is shown principally by the intensity and velocity of the wind; so that in those storms which have small or easy gradients we do not expect to have strong winds, and the contrary with those of steep or rapid gradients.

If, then, the pressure diminishes very slowly the winds are found to be gentle, but if pressure diminishes quickly the air moves rapidly. In fact, just as the water moves faster down a slope the steeper the descent, so also does air move the more rapidly as the pressure diminishes quicker with the distance.

Isotherms and thermic gradient.—Isotherms are lines which unite points of equal temperature. The difference of temperature observed at the end points of the perpendiculars of the different isotherms constitute the heat gradient which we must call horizontal in order to distinguish it from the vertical heat or thermometric gradient, which is the difference of temperature measured along the vertical at different altitudes within a stratum of air. The units for expressing the latter are degrees Fahrenheit per 100 feet in vertical direction, while the former is usually given in degrees Fahrenheit per one-fourth of an equatorial degree—that is, 15 geographical miles. According to modern theories these heat gradients are of great importance in the formation of cyclones.[1]

Daily range of the barometer.—A careful study of the daily course of atmospheric pressure in the Philippines must without doubt be of the greatest importance, not only for the better knowledge of the climate but for the prediction of the formation of cyclones. The daily oscillations of the barometer are so regular in these Islands that by some they have been compared to a clock; and it may be said with certainty that the least irregularities observed in them are generally the most unmistakable indications of the proximity of some atmospheric disturbance. If we examine the curves traced by the barographs in the course of the day a double oscillation of the atmospheric pressure is very noticeable, two maxima being always observed between 9 and 10 o'clock in the morning and evening, and two minima between 3 and 4 o'clock in the morning and afternoon.

Zones in the inferior part of a typhoon.—We further propose dividing the typhoon in its inferior part into 4 zones or rings, A, B, C, and D, corresponding to four distinct barometric gradients, which present marked characteristics in typical cyclones.

---

[1] See Ferrel's "A Popular Treatise on the Winds," New York, 1893, and "Sulla teoría dei cicloni," Luigi de Marchi, Milan, 1893.

Movement of the barometer in the different zones.—The object of the present chapter is to describe simply the different elements of a typhoon. It will be enough to remark that barometrical pressure is distributed very unequally in the different zones. The region A, Plate I, is characterized by an easy gradient (see curve *a*), which does not obliterate the daily range. In region B there is indicated a depression, but not in such a way that the barometer does not show the daily range, since it might be under the influence of the general conditions of the atmosphere (as is indicated by curve *b*). In region C, however, a rapid fall sets in, as it is probably under the sole action of cyclonic movement (see curve *c*). In the vicinity of the vortex—that is, in region D—the descent is very rapid, as is shown in curve *d*.

The curves *a, b, c,* and *d* are not fictitious ones, but correspond to different cyclones which have been observed at Manila. From this we may infer that in the locality on the outskirts of region A, or on the chord somewhat distant from the vortex, the barometer falls, but without losing its periodic diurnal and nocturnal oscillations.

If the position of the observer is in zone B he will notice that the barometer has a more marked descent, with some alteration in the time of its minimum, but without losing entirely the oscillation due to atmospheric effects.

If the position of the observer is very close to, or if he is crossing, zone C, he will observe a barometrical curve similar to curve *c* on Plate I.

Whereas if the position of the observer is in the central area D, the descending movement of the barometer will be continued with extraordinary rapidity.

Therefore, the observer having his position in—

A, the vortex is far off (at a distance of from 120 to 500 nautical miles);
B, the vortex is near (at a distance of from 60 to 120 nautical miles);
C, the vortex is very near (at a distance of from 10 to 60 nautical miles);
D, the vortex is quite close (at a distance of from 0 to 10 nautical miles).

The principle of the divisions we speak of, and the practical use we derive from them, we shall speak of further on.

Direction of the wind.—The same theoretical figure on Plate I also gives an idea of the direction of the winds, and of their bearing with respect to the vortex.

If in the vicinity of a typhoon, the wind blows from the fourth or the first quadrant—that is, from directions between west and north or between north and east—the vortex approaches the place of the observer and he is in the anterior or approaching part of the typhoon.

If, on the contrary, the winds come from the second or third quadrant—that is, from east to south or from south to west—the vortex is passing in front of the observer or has already passed and the place of observation lies in the posterior part or in the retreating semicircle of the typhoon; in other words, the rear of the cyclone has been reached.

This is the fundamental basis of the explanation of the popular barometer by P. Faura. Further on we shall show the scientific principle of these assertions and their practical use.

The inclination or convergence of the wind or the bearing angle.—To understand what we have to say concerning the inclination of the wind it is necessary to note that, setting aside the progressive movement, the air in a typhoon, as far as the internal movement is concerned, is influenced by two forces which we may call the rectangular components. The first force operates in the direction of the gradient, and therefore radially; the second, which has a revolving motion, operates tangentially; the direction of the resulting motion, therefore, depends on the relative magnitude of these two components. In the lower part of the atmosphere the direction of the radially operating power is from outward to inward; the resulting motion toward the center will therefore form an angle with the tangent, representing the convergence of the wind, or the bearing angle. Since the radial component of the movement of the air in its vortical circulation gradually decreases in force in proportion as the air nears the center or vortex, being small near the vortex and very small or almost zero in the vortex itself, whilst the revolving and tangentially operating component grows and is greatest near the center, it follows that the angle of bearing of the resulting motion near the center must be small if compared to those in the outer zones of the cyclone, and must approach a circular motion. The progressive motion of the cyclone influences the convergence of the wind also, which, in the anterior portion of the cyclone, especially in zone A, may likewise be more or less affected by the prevailing (general) wind.

The body of the cyclone.—It is not only the lower strata of air which participate in the cyclonic movement but the upper strata to a considerable altitude are also influenced by it. We may picture to ourselves the body of a cyclone as having the form of two truncated cones in inverted position, one on top of the other, their smaller bases being in contact. In both truncated cones the aerial currents move in ascending spirals. In the lower spiral the motion is opposite the direction of the hands of a clock and is convergent to the center. In the upper spiral, however, the strata of air follow a motion which coincides with the movement of a watch hand, and is divergent from the center. In the Southern Hemisphere the directions are opposite.

The indications of these movements are the barometrical readings, and their effects are the destruction they bring about, and the swell on the sea which is often their first forerunner.

Bar of the cyclone and banks of clouds.—The cirrus clouds stream forth in vast tufts from the upper portion of the body of the cyclone, and in the lower parts of the spirals of the cyclone field very large masses of black and dense clouds begin to drift past. Part of these follow the wind and produce deep darkness and copious rain. These clouds, generally *strato-cumuli* and *nimbi,* conjointly make up the bank of clouds known as "the bar of the cyclone."

Each of these motions, and also the direction of the clouds at the different levels, and the direction of the swell, taken with the simultaneous fall of the barometer, are of great value in fixing the position of the center.

"When a cyclonic storm has formed," says Eliot,[1] "large masses of air are carried rapidly upward in the body of the cyclone or over a considerable portion of the inner storm area. The aqueous vapor with which it is laden is in part condensed rapidly. Huge nimbus, pallium, or rain clouds are formed, from which rain is poured down in torrents. Hence, over the central area there is a permanent, dense, black mass of clouds which moves with, and is a part of, the cyclone. This permanent state is, of course, one of appearance or passage only. The air as it rises up and passes through the cloud-charged space has a portion of is aqueous vapor condensed, and thus contributes or adds to the mass of the cloud, whilst at the same time the cloud is continually losing a portion of its mass by the rainfall. The cloud mass is hence in a state of constant growth and decay. Its appearance at a distance is that of a huge bank of clouds resting on the horizon, which retains its form unchanged for hours. It is usually most conspicuous about sunrise and sunset. If a ship should travel at about the same rate as the cyclone this huge bank of clouds may be observed for several days in succession."

Axis of the cyclone—Nutation—Absolute and relative calm.—The two large, ascending spirals, one of which has a convergent, the other a divergent, movement as regards the center, inclose the axis of the cyclone. Plate II gives a vertical section through a cyclone in which the axis has two directions—OE and OE′. These two directions of the axis indicate to us a nutation, which may influence the violence of the wind and possibly the whole cyclone. Redfield ascribes to the nutation of the "gyral axis" the great variety in the force of the wind at equal distances from the center, and likewise the squally nature of the strong winds. If the axis is vertical the annular relative calm and the central absolute calm are confined within regular limits. If the axis, however, assumes the inclination OE′, and if the cyclone is advancing in the direction of the arrow MN, the zone of relative calm disappears almost entirely in the front, but grows correspondingly larger in the rear. If by this direction of the axis the area of absolute calm should become smaller the clouds and winds in the front will be at the same time lower, and the latter will consequently be much more violent than in the rear and the *cirri* will stream out in front at a lower altitude. If we take for the same direction of the axis the progressive movement of the cyclone to be in the direction NM, the contrary of what has just been said will take place. If the axis should incline toward one of the sides the "manageable" and "unmanageable" semicircles may be inter-

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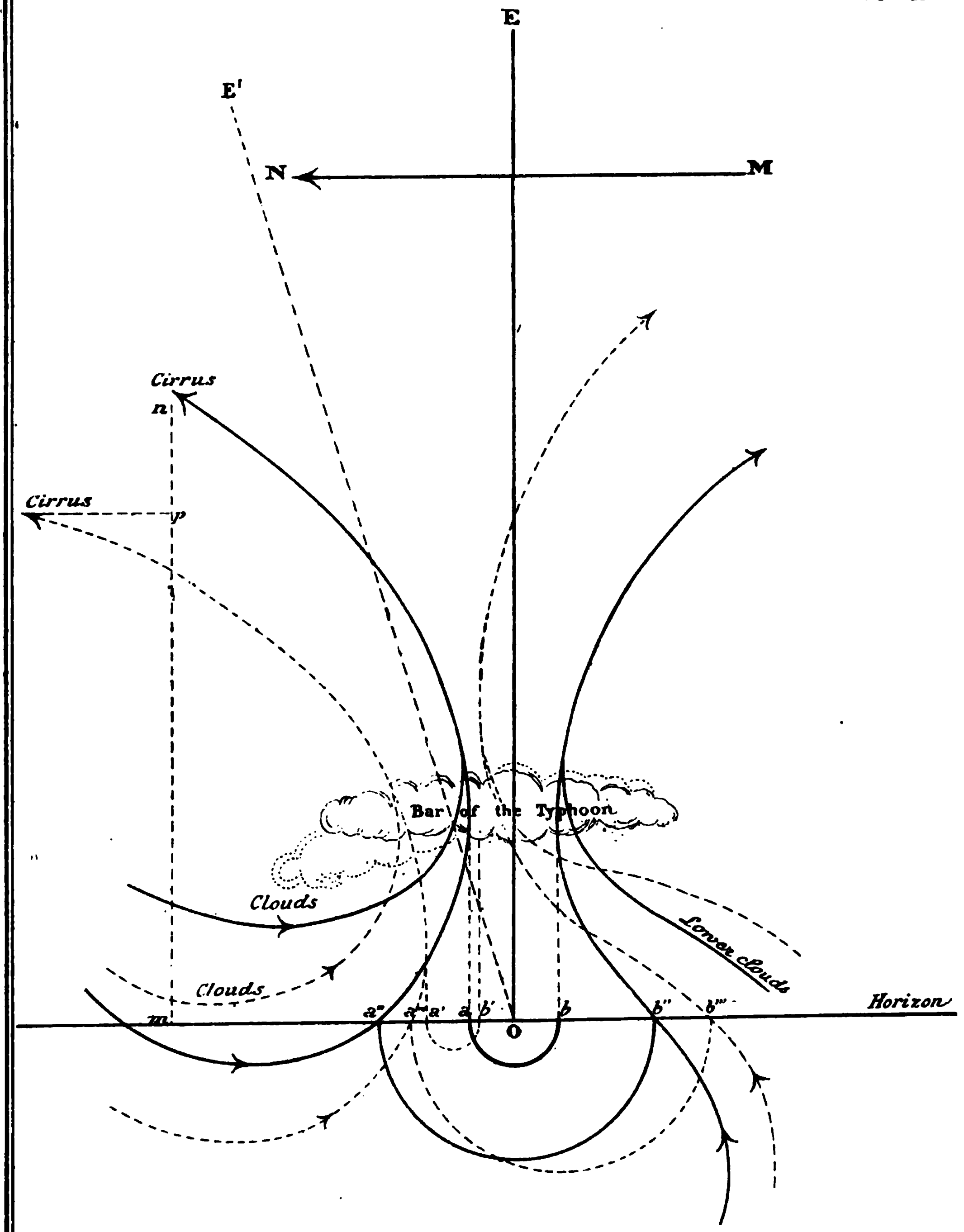
[1] "Handbook of Cyclonic Storms in the Bay of Bengal," p. 131. Calcutta, 1900.

Plate II.



$\left.\begin{array}{l}\text{a b}\\ \text{a}^1\ \text{b}^1\end{array}\right\}$ = Diameter of the absolute calm. $\left.\begin{array}{l}\text{O E}\\ \text{O E}'\end{array}\right\}$ = Axis.

$\left.\begin{array}{l}\text{a}''\text{b}''\\ \text{a}'''\text{b}'''\end{array}\right\}$ = Outer diameter of the annular relative calm.

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changed, as is easily understood. Hence is is clear how great an influence the position of the axis exercises upon the elements constituting a hurricane, but above all that, supposing the oscillatory movement of the cyclone's body, it is a perilous idea to consider the dangerous and safe semicircles as occupying fixed positions. However, in that part of the tropical zone which comprises the Philippine Archipelago the progressive movement of the cyclones is not very great in comparison to the gyratory motion. Hence the component due to the advance of the storm is not sufficiently great to have much of an influence upon the velocity of the wind and upon the other elements of the phenomenon. Consequently the difference between the "manageable" and "unmanageable" semicircles is not so pronounced as some meteorologists suppose it to be.

Progressive motion of cyclones.—Tracks or routes of cyclones differ from each other in the various seasons, as we shall see in a separate section of this work in which we deal with the progressive motion of the cyclones.

Depressions and cyclones.—In order to give a better insight into the subject, we call attention to the fact that in the Far East two classes of atmospheric alterations are to be distinguished. The name commonly given to one class is *depressions* or *areas of low pressure,* and to the other *cyclones* or *typhoons.* We shall deal hereafter with this second class, but a few words concerning the first class are deemed necessary here.

Depressions.—For the sake of clearness we shall consider the depressions divided into two groups, namely, those originated in low parallels between 4° and 12° latitude north and those formed in higher latitudes, probably between 16° and 22° latitude north.

Depressions in low latitudes.—There are areas of low pressure uniformly extended over an immense region, occurring chiefly during the months of December, January, February, and March. In most of the cases it is hardly possible to distinguish in these depressions a true motion of translation or to determine their center, as pressure begins to fall and reaches its lowest point at one and the same time in the whole Archipelago and most likely in a great portion of the Pacific Ocean and China Sea. They are rare in February, but more frequent in December, in the first part of January, and in March.

Effect of these depressions.—The immediate effect of this kind of atmospheric disturbances is the development of moderate and gusty winds from the first quadrant and rains more or less abundant in Visayas and Mindanao, in the China Sea from Paracels to the west of the central Palawan Island, and sometimes this effect is felt in the provinces of southern Luzon.

Generally there is no true cyclonic circulation around such extended areas of low pressure, but whenever it has been possible to locate the center of any one of these depressions between the Visayas and Mindanao it has been observed that in the southern part of the area moderate or brisk winds from south to southwest prevail. The fall of the barometer in the inner part of these shallow depressions seldom amounts to more than 4 millimeters (0.15 inch) below the normal height.

It will be worth while remarking that some of the depressions of the kind described after having crossed the meridional zone of the Philippine Archipelago in the form of a shallow depression with a little more definite limits than in the average cases acquired a greater degree of development in the southern China Sea.

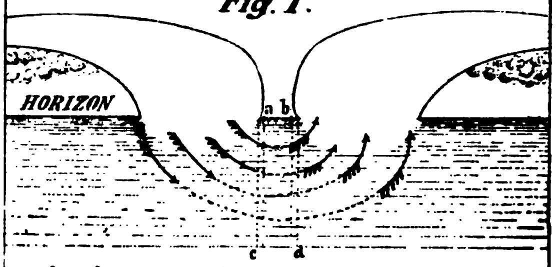
Depressions in higher latitudes.—The depressions which lie in higher latitudes are also wide areas of low pressure or shallow depressions prolonged from east to west or from east-northeast to west-southwest, which usually remain stationary for some days to the northwest of Manila, between the northwest of Luzon and the south of China, or in the Pacific toward the northeast or north-northeast of Manila. It is not infrequent to observe them lying along the Baschi and Balingtan Channels extending from the south of the channel of Formosa to the south of the Liukiu Group. These depressions are apt to occur during the typhoon season, especially in June and July.

Effect of these depressions.—There is no well-defined cyclonic circulation around these areas, but toward the north of them brisk winds from north to east prevail and also to the south winds from south to southwest blow with intermittent force and occasional squalls. As these depressions remain stationary sometimes for several days, rough weather prevails also for several days, mostly to the south of them, thus constituting the phenomenon known to the natives of the Philippine Archipelago by the name of *colla*. The same effect is at times produced by true typhoons when they move with great slowness in the Pacific to the northeast or north-northeast of Manila or when they follow one another almost without interruption in the Pacific itself, or, finally, whenever some typhoon recurves either on the continent or somewhere in the north of the Archipelago. Shallow depressions in high latitudes sometimes give place to the formation of genuine cyclone centers.

Cyclonic center filling up.—Shallow depresssions are at times converted into true cyclonic storms, as indicated, and genuine cyclones not infrequently degenerate into shallow depressions. This phenomenon never or very seldom occurs in low latitudes. In such cases the barometric gradient progressively diminishes and the inner cyclonic area fills up entirely or is converted into a shallow depression, as is shown by the above-described effects and especially by a moderately low barometer without a considerable veering of the wind for a long time.

CENTRAL AND VERTICAL SECTION OF AN ORDINARY CYCLONE

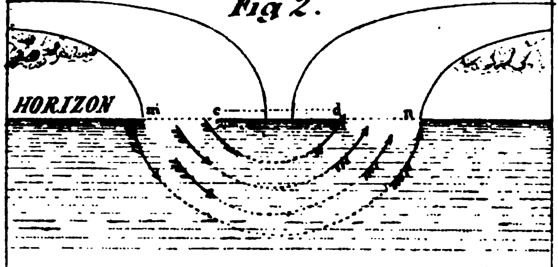
Fig. 1.



a b – diameter of the area of vertical calm.
c d – diameter of the ring area of relative calm.

CENTRAL AREA RISEN ABOVE THE HORIZON

Fig 2.



c d – diameter of the area of relative calm.
m n – diameter of the ring area of strong Winds.

Descent and ascent of the nucleus of a cyclone.—In some cyclones an ascent of the inner part has been noticed. In tropical hurricanes only the inner part of the body of the hurricane rises and sinks, not the whole whirl, as is the case with tornadoes and waterspouts. The "Bokhara" typhoon of October 8 to 12, 1892[1], and the typhoon of September 27 and 28, 1894, are proofs of this phenomenon. The two subjoined sketches show in what way this ascent and descent takes place. They are taken from Chevalier's work already mentioned, as modified in the work "Baguios ó Tifones de 1894."[2]

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[1] Chevalier, "The Bokhara Typhoon." Shanghai, 1893. 32 pp.

[2] Algué, "Baguios ó Tifones de 1894." Manila, 1895. 96 pp.

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CHAPTER II. ORIGIN OF CYCLONES.

It is possible to treat the question as to the origin of cyclones from two points of view. The physical conditions under which they originate may be investigated, or else we may seek to discover the regions in which they take their rise. As to the physical causes for their origin, there is among meteorologists a great difference of opinion and their views stand frequently in great contrast to each other.[1] It is doubtful, however, whether a correct knowledge of the causes which originate and maintain a cyclonic disturbance would be of much practical importance in the way of enabling better forecasts to be made, but the subject is one of so great importance, and also it may be said of such complexity, that a discussion of the problem should be welcome.

Hann writes in the Journal of the "Oesterr. Ges. f. Meteorologie" in Volúme X, 1875, page 81, with regard to this matter, as follows:

> The older theory views the storm whirls, if I may call them so, from an entirely mechanical point of view, as being caused by the meeting of various air currents. As reason for the low air pressure in the center of the cyclone is assigned centrifugal force, which again is a consequence of the rotation of the air. We have lately read in this same journal a detailed statement of this theory by Dr. Wittwer. The newer theory, which I should like to term the physical one,[2] considers the local appearance of a low barometer to be the first cause of the influx of air from all sides, and, owing to this, through the influence of the earth's rotation, the whirl is formed. This theory explains the low atmospheric pressure itself as being a consequence of the condensation of aqueous vapor over a considerable area of the earth's surface.
>
> We see, therefore, that, apart from the different explanations with regard to the origin of the whirls, the conflict of views consists in this, that, according to the older theory, the differences of pressures are brought about by the wind, whilst, according to the newer theory, the direction and the force of the wind are only consequences of already existing differences of pressure.
>
> Both theories can not exist alongside each other, but it is not necessary that one of them should be absolutely wrong and the other absolutely right; for in both theories right views may be mixed up with wrong ones. Let us, therefore, examine them in this respect. Nobody can deny that whirls may be formed through the meeting of currents at an angle. But it would be difficult, if not impossible, to explain how in this manner it is brought about that the rotation takes place exclusively from right to left in the Northern Hemisphere and vice versa in the Southern. It is still more difficult to explain, according to this theory, the fact that the whirl once formed should travel through the atmosphere on a path which is hundreds of miles long, drawing thereby continually new masses of air into the rotatory motion, overcoming along its whole route a great amount of frictional resistance and producing a powerful mechanical effect. Without a continuous increase of power this would be physically impossible, and it would even surpass the *perpetuum mobile*. But to assume that all along the route for so great a distance, across so widely different wind regions, there should be a continuous collision of winds at the required angle would appear to everybody as a mere play of imagination.
>
> The new theory as to the origin of the rotary motion through the diverting influence of the earth's rotation upon the masses of air which pour toward a minimum of pressure, entirely explains why their rotation is without exception from right to left in the Northern, and from left to right in the Southern Hemisphere. This theory is the more satisfactory to us for the reason that it points to the source from which the existing whirl always

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[1] "It is evident that the question of the formation of cyclones can not be well settled from the works already published."—Les bases de la meteorologie dynamique par H. H. Hildebrandsson et L. Teisserenc de Bort.. 5 Livraison, 1901, p. 206.

[2] See "Les bases de la Meteorologie Dynamique," 5 Livraison, Paris, 1901. Depuis le commencement de la meteorologie dynamique il a regné deux opinions ou theories sur la formation des cyclones et anticyclones: la *theorie thermique* et la *theorie mècanique* que l'on oppose souvent l'une á l'autre, bien qué elles contiennent probablement chacune une part de verité, p. 193.

receives new power. It uses for this purpose the fact that each of these large air-whirls is accompanied by a copious condensation of aqueous vapor. The latent heat which thus becomes free produces an accelerated rise of the air above the cyclone, and thus continually generates a flow of air from all sides underneath. We now see that the whirl can move onward, and even that it must move onward, if it is to last. The power which it needs, in order to surmount the resistance of friction, to draw into itself masses of air which hitherto were at rest, and to exercise its powerful mechanical influence, rests already stored up in the air along the route on which it is to travel. This power is still latent, but the approach of the cyclone unchains it. Wherever the whirl finds no sufficiency of aqueous vapor in the atmosphere, and has at the same time to overcome great resistance from friction, it must quickly come to a standstill. As this newer theory give us thus a sufficient physical explanation for some of the most important phenomena which have to be considered in connection with storms, I have taken the liberty to call it briefly the "physical" theory.

The explanation of the barometrical minimum simply through condensation of aqueous vapor is, however, not equally satisfactory. I have already expressed myself sufficiently in this journal[1] as to the reasons which necessitate the rejection of the view according to which, no matter in what way, a considerable decrease of air pressure on the earth's surface may be produced through the condensation of water-vapors, a principle which, though in itself correct, has been used for extreme conclusions, which are neither justified by theory nor borne out by facts. I have already remarked that, according to my belief, the greater part of the barometrical depressions during storms must be explained in a mechanical way.

It is strange that the new theory of storms does no longer take centrifugal force into consideration at all, and that it overlooks another similar effect, although it fully needs this latter in order to account for the changes in the directions of the wind. The older theory uses centrifugal force in order to explain the rarefaction of the air in the center of the whirl; but as far as I am aware, I have never hitherto met with a German publication which would show us, if only approximately, how great are the differences of air pressure which can be due to the centrifugal force of rotating masses of air, and furthermore, whether these differences suffice to explain either the whole or at least the greater part of the pressure differences as they appear in cyclones.

It may be well to say it right here, that we do not intend to explain all differences of air pressure as being a consequence of the movement of the air masses themselves; this extreme would be as objectionable as the other. We merely hold that the greater part of the great local differences of air pressure noticed in a whirlwind, or even in a straight-moving air current, if any such exists, is the result of the movement of air. The latter has, however, its origin in a difference of pressure originally smaller but more general.

Hence, according to Hann, neither of these two theories suffices to explain the origin and the continuance of cyclones. The former may perhaps explain the origin of a cyclone[2] in an isolated case, but it can not generally explain its origin, development, and duration, and much less its progressive movement. On the other hand, the latter theory treats the causes of the origin, the duration, and the motion of cyclones, but without taking sufficiently into consideration the first cause of the phenomena. According to this theory, therefore, any meteorological factor capable of altering the state of atmospheric equilibrium existing over an extensive region may become the occasional cause for the formation of cyclones. Whenever the equilibrium over a larger area becomes thus disturbed, the surrounding air endeavors to restore it, and the motion directed towards the region of low pressure is influenced by the earth's rotation, and by the centrifugal force. These two powers produce the whirl, and they are the cause for a further fall of the barometer. Ferrel was the first to treat the changes of pressure in a cyclone mathematically, as being a consequence of the centrifugal force, and of the earth's rotation. The vertical cyclonic activity he attributes to the horizontal and vertical thermic gradients.

If this be so, why can we not suppose that the origin, that is to say, the primary factor of some cyclones, is precisely the action of opposing currents, originated by the thermal conditions of the atmosphere or by other causes whose immediate effect is the whirl, from which comes the barometric depression and the consequent alteration of the atmospheric equilibrium which produces the convergent currents? In such a case the convergent currents would subsist even though the opposing currents had disappeared, leaving the whirlwind thus formed by virtue of the general causes which the new theory assigns, just as if it had been formed by the condensation of aqueous vapor over a large area. This seems to be the origin of many of the cyclones of the China Sea, especially of those which are formed while another is crossing the Pacific.

Keller assigns implicitly an electrical origin to the cyclones. His views are to be found in

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[1] Meteorol. Zeitschr., Vol. VIII, p. 102; Vol. IX, p. 289; Vol. X, p. 11.

[2] Compare also Knipping in "Annalen f. Hydr. u. Mar. Meteorol.," 1895, p. 340.

"José M. Tuero, Tratado elemental de los huracanes," Madrid, 1860, page 78," and in "Solaro, Recherches sur les causes et les lois des mouvements de l'atmosphère," Paris, 1885."[1]

W. C. Redfield speculated on the cause of the hurricanes which visit the Atlantic coast, and conceived that—

> They originate in detached and gyrating portions of the northern margin of the trade winds, occasioned by the oblique obstruction which is opposed by the islands to the direct progress of this part of the trades, or to the falling off of the northerly or eddy wind from the American coast upon the trades, or to both these causes combined.

In an essay by Frank H. Bigelow, "Solar Magnetism in Meteorology," in the American Meteorological Journal, January, 1895, page 319, the formation of cyclones is brought into very close connection with the action of solar magnetism.

This author in a more recent work[2] deals with the origin of cyclones in such a way as to seem to confirm the views we expressed commenting on Dr. Hann's theory. He says:

> **Discussion of the causes of local cyclonic gyration.**—The general aspect of these charts [by Teisserenc de Bort on the circulation of the atmosphere] is, it must be claimed, strongly in favor of the view that the cyclonic circulation is the product of two or more long horizontal streams, which are maintained by extensive horizontal gradients of temperature, located far beyond the territory of the cyclone, meeting together in a counterflow, which, by an action similar to that of a couple, rotates the air brought into contact in a whirlpool of gyration. The sources of supply are at least two thousand miles distant, and it is inconceivable that any local vertical convection at the lakes should have so enormous a reach as is here shown to exist in the cumulus level. Furthermore, if vertical convection is the cause in the wind and cumulus levels, why does it not show much more decisively in the cirrus levels as a cyclonic rotation, where we perceive on the other hand only a very moderate deflection. Also, it will be remembered that the nephoscope measures give very feeble indications of a true cyclonic component above the cirro-cumulus level, or 8,000 meters * * *.
>
> The cause of a vertical component is, however, readily accounted for without convection, as we shall show analytically, by simple vortex motion, provided a gyration is set in operation and maintained from other sources. A vortex consists of a rotation about an axis, accompanied by a current along the axis proportional to twice the angular velocity of the gyration. The magnetic whirl with an electric current through it is an example of a similar kind, and the mathematical principles of one apply generally to the other. While the air flows eastward, it is sinuously deflected to the north of a High and to the south of a Low, and there is developed from the bottom to the top of a Low area a whirl with only inward gradients, whose gyrations are necessarily accompanied by a vertical component due to the purely vortex motion. The analogy is quite good between the battery, the magnetic field surrounding a wire, and the electric current, along the wire on the one hand, and on the other hand those meteorological formations here described. For the temperature gradients produced by solar insolation, and the constant tendency to preserve a normal equilibrium on the rotating earth, guided and modified by the mutual action of the air lying over the continents and oceans acting upon each other, is like the battery which is the source of energy; the rotating components about the axis of the Low, caused by the counterflow and interference of streams from different directions impinging upon each other, are like the circular magnetic lines of force about the conductor; and the vertical component lifting the air of the central region, where *closed isobars* are developed, is the analogue of the electric current itself. Those who are familiar with the theory of electricity and magnetism, as well as the hydrodynamic equations of vortex motion, will recognize that we deal with the same theoretical principles under two aspects. In fact, the equations of motion of these two subjects are practically identical—one being concerned with lines of force in the ether, and the other with stream lines in the atmosphere. While, therefore, local heating of the lower air may have much to do with causing vertical convection in summer, during the winter, since the ground is relatively too cool for true adiabatic gradients, we must look to the mechanical cause just described for the raising of the air near the center of the Low, rather than to pure convection. This vortex vertical component lifts the air, causes cooling by expansion, and it is thus a most efficient cause of precipitation, which is chiefly an effect; of course the generation of its latent heat also assists the vertical action. The intermixture of masses of cold and warm air from different regions also aids in the process of condensing the aqueous vapor, and hence to precipitation. This general view seems to be supported not only by the components and gradients derived from the nephoscope vectors, but also by the configuration of this set of charts; it is entirely efficient in its mechanical details, and so easily overcomes the difficulties inherent in the purely vertical convectional theory that we have

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[1] "The views of Keller are entirely differently represented in his essay 'Des ouragans, tornados, typhons et tempêtes.' Annales maritimes, 1847. The cyclones originate, according to that view, through monsoons which move in different directions, striking against each other in a zone of very great heat." Bergholz, The Hurricane, etc., p. 12.

[2] The International Cloud Observations. Report of the Chief of the United States Weather Bureau, 1898–99, Vol. II, p. 446.

not hesitated to accept it in our discussion as having the evidence of truth. It accepts the Ferrel vertical convectional action at its real value: it also admits the general validity of Dr. Hann's explanations of the formation of cyclones and anticyclones in middle latitudes.[1]

Coming now from theory to fact, we think the following article, "On the origin of typhoons and hurricanes," written by the editor of the Monthly Weather Review, deserves special attention in this place:[2]

> The study of the formation and development of cyclones has been followed with the greatest minuteness under exceptionally favorable conditions by the meteorologists of India. In a recent essay ("An account of a storm developed in equatorial regions," Calcutta, 1896) Mr. W. L. Dallas has endeavored to decide whether the inrush of a saturated stormy wind from the southwest into a region of heated moist air is essential to, or the determining cause of, the formation of a cyclonic whirl. He finds that it is not necessary and gives in detail the facts of a special case over the Bay of Bengal between the 1st and 15th of December, 1894. His conclusions are favorable to the general correctness of the ideas developed by Professor Ferrel who, as is well known, gave a more precise expression to the principles taught by Espy. According to these meteorologists, when a general uniformity of pressure and quietness prevails in the atmosphere, especially over the ocean, and when the quiet air becomes so warm and moist that ascending currents and clouds are forming here and there over the warm region, then any one of these ascending currents may be so fed with moist air as to steadily increase in its volume and instability; it rises and the surrounding air that is drawn in begins a gyratory motion, usually in the cloud regions, but which is soon propagated downward to the earth's surface. The quiet region in which the instability first occurs is often that which is called the doldrums; if this is not located at the equator, but five or ten degrees north or south, depending on the season, then the gyration of the winds around the center is fully determined by the deflecting action resulting from the diurnal rotation of the earth on its axis.

In summing up the results of his study of this storm Mr. Dallas says:

> On the first three days of December, 1894, the Indian daily weather charts exhibited a typical illustration of the ordinary meteorological conditions which theory assigns to the Belt of Calms. An area of continuous low barometer lay over the equator, on either side of which the two trade-wind currents blew freshly, while within the area itself the surface winds were very light and variable. The weather was fine generally, but daily, at 4 p. m., just after the diurnal period of greatest evaporation, heavy precipitation of rain took place. The charts for these days show, then, a more or less inclosed area within which the weather was fine, and constant evaporation was proceeding with apparently no horizontal outlet for the accumulating aqueous vapor. On the 3d of December the southeast trades seemingly began to take off, but the observations on this day show that nearly all the ships in southern latitudes had entered or were close to the inclosed area of light and unsteady winds and low barometer. The sky was densely clouded, and though heavy rain fell for a time during the later hours of the day, this outlet was probably insufficient to stay the steady accumulation of aqueous vapor over the inclosed area. In the afternoon of this day (3d) the vessel *Falls of Garry*, in latitude 5° south, reported the cessation of the southeast trades, their replacement by light, variable, "puffy" breezes and heavy rain. By the 4th the process of accumulation of aqueous vapor had apparently reached its maximum and the subsequent condensation had set in. A continuous downpour of rain was reported, and this was accompanied with light, variable airs and calms on all the ships within the inclosed area. At the same time, as the constant rapid condensation proceeded, so did atmospheric pressure diminish, so that by the morning of the 6th a well-defined central area of depression had been developed within the inclosed area almost directly over the equator. It is interesting to note that, so far as can be judged from the observations at the period when the process of constant evaporation had resulted in a saturated condition of the atmosphere over the inclosed area, and the subsequent process of sudden, rapid, and extensive condensation had succeeded, there apparently occurred a slight but appreciable rise of pressure over the whole equatorial region under observation. This rise was shown by the chart of 8 a. m. of the 4th (not reprinted), and it will be remembered that it was after 4 p. m. on the 3d that the process of rapid condensation set in and became the most important of the changes in progress over the area.
>
> If the above be the explanation of the initiation of the storm, then further inquiry would be unnecessary, as the principle of evaporation and condensation is a general and not a local one and is as applicable to equatorial regions as to other parts of the earth's surface. Further it is necessary from this point of view to introduce a force to account for the gyratory motions, as the theory presupposes an irregular inflow of the surrounding air as pressure diminishes, an inflow which can only result in a vorticose or spiral motion of the atmosphere converging toward a center, while for the gradual increase in the intensity of the barometric depression and

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[1] An interesting paper on the mechanism of counter currents of different temperatures in cyclones and anticyclones, by the same author, is to be found in the United States Monthly Weather Review for February, 1903.

[2] United States Monthly Weather Review, Washington, 1896, pp. 417, 418.

> in the force of the winds an adequate cause is assigned in the rapid condensation and precipitation of rain accompanying the inflowing currents of air when once the center is developed. * * * Two minor points of interest connected with the disturbance deserve perhaps passing notice. The first is the torrential rain which accompanied the disturbance throughout its course. This rainfall was apparently associated with a stream of air from transequatorial regions, and as soon as this supply was cut off and the wind shifted to northeast again, to the south of the disturbance the rainfall decreased and the intensity of the disturbance diminished. The second is the sharply defined limits of the disturbance. Hardly any indication of the presence of a storm was afforded by the coast observations.

General remarks on the regions in which tropical cyclones are originated.—Father Viñes, speaking generally about these regions, says:[1]

> It must, of course, be admitted that the tropical cyclones do not form indefinitely at any point within the tropical zones, but that they single out, in preference, for their formation and development particular and definite regions in those zones. The following geographical conditions generally, and in a more or less perfect degree, distinguish the cyclonic regions within the tropics: Large continents lie to the west, indented by numerous gulfs and bays whose coasts run more or less northward and southward, with vast and extensive seas to the east, overspread commonly with numerous island. Such, at any rate, are the features that in more or less perfect degree concur in the cyclonic regions of the Philippine Isles and in the China Sea, in the seas of India, and also in the Southern Hemisphere in the region situated east of Africa, in the vicinity of the islands of Madagascar, Mauritius, Reunion, Rodriguez, etc. But of all the cyclonic regions within the intertropical zone the one which more perfectly combines all these conditions is the great Bay of North America, with its wide Atlantic Ocean extending to the east as far as the coast of Africa, and to the northeast as far as the coast of Europe and the northern seas. * * *

We may say, indeed, that there are in the Northern Hemisphere two main zones for the formation of tropical cyclones; one to the east of the southern part of North America, the other to the east of the Asiatic continent, and both are about 180° apart in longitude. Two minor regions of formation lie, one in the Indian Ocean south of the Bay of Bengal and of the Arabian Sea, and the other close to the western coast of Africa; both regions differ about 110° in longitude.

The place of origin is not always in the same spot or in the above regions, as it changes slightly in the different seasons of the year, at least, as far as the zone of origin for the tropical cyclones in the Far East is concerned.

Investigation based on experience of the regions of formation for tropical cyclones in the Far East.—This investigation is exclusively compiled from experience. The trajectories of the cyclones studied from 1878 to 1901 have been grouped according to months. By this grouping we are able to see in a graphic manner the intertropical region of formation which corresponds to each month. We may mention that, previous to receiving observations from the Carolines, Marianas, and from the east coast of Mindanao, it was difficult to study typhoons from their region of formation, consequently in some of the trajectories published in the maps ("Baguios or typhoons of 1894," second part, p. 141), the origin is not marked as having been examined, but only the position of the vortex, the day on which there were certain indications of its existence, laying aside the question whether it existed before, or was of recent formation.

With the assistance of observations from the Carolines and Marianas we have been able to fix with sufficient precision the places of the formation of many typhoons, in fact of nearly all that have been observed in recent years, and from these has been deduced the mean region of formation of typhoons, corresponding to each principal epoch of the year, which for this purpose is divided into the following groups:

December, January, February, and March constitute the first group; April, May, October, and November, the second; and June, July, August, and September, the third.

The mean zones of the trajectories and the regions of formation are seen in the general map, which we insert to demonstrate the progressive movement of typhoons.

Father Stanislaus Chevalier remarks in his treatise on the origin of typhoons ("The typhoons of the year 1893," p. 88):

> There are typhoons which originate in the China Sea, but they are very few. * * * Very commonly the typhoons originate east of the Philippines, in the square roughly included within meridians 125° and 145° East

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[1] United States Weather Bureau pamphlet No. 168, 1898. West Indian Hurricanes. United States Weather Bureau Bulletin H, 1900, p. 10.

of Greenwich and the parallels 10° and 25° North. Whether they originate further eastward is not sure, but it is rather probable. But if there are some, they do not come so far westward as to make their appearance either on the China or on the Japan coast.

This is mentioned by the Hydrographic Commission, of Washington, in their pilot chart of April, 1895 ("Pilot chart of the North Pacific Ocean, 1895").

Touching the zone of formation, we should have said in the preceding paragraph that, generally speaking, there are many typhoons which form in a lower parallel than 10° N., and very few in a higher parallel than 20° N. somewhere to the east-northeast of the north of Luzon. With regard to the longitudinal limit of formation assigned by Fr. Chevallier, we judge it to be sufficiently approximate for those of which he speaks, as well as for those which are experienced here in the Philippines and in Japan. We do not speak of China because we know for certain that there are no typhoons experienced in China, Tonkin, or in Cochin-China, which have not previously exerted their influence over the Philippine Archipelago, not even those which are accidentally formed in the China Sea.

This refers chiefly to the cyclones which are in some way or another felt in the Philippines. Taking into consideration the cyclones which we classify in Chapter X as cyclones of the Marianas and Magallanes, we can extend the limits in longitude for the cyclones formed in the Pacific to meridian 125° to 152° East of Greenwich.[1]

In order to be quite clear, we shall indicate the probable zones, corresponding to each of the three groups of months, into which we proposed to divide the year.

December, January, February, and March.—The greater part of the typhoons which develop during these months are formed in latitudes lower than 10°, but the region of formation is displaced in the beginning of December and at the end of March, moving somewhat further to the north, so that, generally speaking, the region of formation for this group is circumscribed by the parallels 12° and 5° north and the meridians 145° and 143° east of Greenwich. (See tracks on general chart.)

April, May, October, and November.—It is worthy of note that during the month following each group there may appear typhoons that have the characteristics of those of the preceding group. Thus, for instance, notice typhoons in the beginning of October which have the character of September typhoons, but they must, nevertheless, be considered as belonging to the second group; and the same may be said of the November and December typhoons.

The region of formation of the typhoons of the second group has a wider spread than that of the first; it extends from 17° to 6° north, and from 142° to 129° east of Greenwich, as can easily be verified by inspecting their trajectories.

June, July, August, and September.—The region of the third group lies between 20° and 8° north, and between 139° and 126° east of Greenwich.

It will be of interest to learn the physical conditions under which the formation of cyclones takes place in the various seasons. We use for this purpose the isobar and isotherm charts, which our observatory has published in the year 1894 in the "Boletin Mensual." (Pls. IV–XV, Chap. VIII.)

The zone of the first group is confined to the isobars 757 and 759 millimeters (29.80 and 29.88 inches) and the isotherms 27° and 30° C. (80.6° and 86.0° F.). The barometrical and thermometrical gradients are, therefore, very small. The prevailing directions of the wind are, according to Coffin ("The winds of the globe"), northeast to north-northeast.

The zone of the second group lies, just as that of the first, between the isobars of 757 and 759 millimeters (29.80 and 29.88 inches), and the isotherms of 28° and 30° C. (82.4° and 86.0° F.). In October and November west-southwest prevails, but northeast in April and May. (Coffin, Chart 20, p. 752.)

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[1] There is on the map a track of a cyclone observed on the 28th of December, 1892, to the 2d of January, 1893, which ran fully developed from the meridian 151° or 152° East of Greenwich according to the very valuable observations made on board the S. S. *Venus* bound from Ponapé (Eastern Carolinas) to the Marianas Islands.

The zone of the third group lies in September along the isobar of 757 millimeters (29.80 inches); during the other months, however, it lies between those of 757 and 759 millimeters (29.80 and 29.88 inches). It is bounded by the isotherms of 28° and 29° C. (82.4° and 84.2° F.). The mean direction of the wind is west-southwest in September and southwest during the other months. (Coffin, Chart 50, p. 752.)

Hence it follows that the cyclones form neither in a region of low nor in a region of high pressure, but in a sort of neutral zone.

The temperature is in all three zones about the same and the thermic gradient almost equal to zero.

Relation between altitude of sun and latitude of the zones of origin.—From February to July and August the zones, gradually becoming wider, travel slowly toward north-northwest, to return again by January to south-southeast. This movement shows that there is a connection between the suns declination and the regions for the origin of the cyclones.

MERIDIAN ALTITUDE OF THE SUN IN MANILA.

Month.	Mean values.	Month.	Mean values.
	°		°
December	54–56	June	99
January		July	97
February	64	August	90
March	76	September	78
April	81	October	68
May	94	November	58

During the months of the first group, we find the sun at its minimum altitude in Manila and with a declination smaller than that of Manila.

During the months of the second group it is at its middle altitude; and during those of the third we find it constantly in the northern hemisphere, and with greater declination than that of Manila. The middle altitude of March differs, indeed, a little from that of September, but we must remember that during March the movement of the sun is ascending whilst during September it is descending, and in consequence the thermic effects of the sun, which for the previous six months has continually been in the Northern Hemisphere, may still prevail during the next following months. For an analogous reason, although the sun reaches the zenith of Manila already towards the end of April, all the zones of high parallels are only gradually developing under its action as this heavenly body advances into the Northern Hemisphere.

Probable limits of the zone of formation of cyclones originating in the China Sea.—The number of these baguios or cyclones is relatively insignificant when compared to the many which are formed in the Pacific, and therefore we will briefly say of them that the zone of their formation may be limited by the fifth and twentieth parallels and the one hundred and twelfth and one hundred and twentieth meridians east of Greenwich. It is to be noted, nevertheless, that those formed between the fifth and fourteenth parallels[1] are few in number and the great majority of them are formed between parallels 14 and 20 to the west or northwest of Luzon and almost always at a distance from Manila greater than 120 miles.

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[1] In the trajectories published by the Hongkong Observatory we frequently find typhoons which appear to be formed in the China Sea to the northwest or north of Paragua, between the tenth and fourteenth parallels; but remembering the notices of typhoons given by our Observatory, it will easily be seen that many of said baguios did not originiate in the China Sea, but proceeded from the Pacific and crossed the Archipelago by way of the Visaya Islands or of Mindanao, previous to following the trajectory traced by the director of the Hongkong Observatory. It will be sufficient to record, in confirmation of this, the typhoon of the 7th to 12th of June, 1895, which placed the merchant steamer *Bohol* in such great danger at the north of Panay Island, as is recorded in the "Revista meteorologica" of our Monthly Bulletin of the said month and year. Therefore, in speaking in his work, "The law of storms in the Eastern Seas," of the typhoons which cross over our Archipelago and enter the China Sea by parallels lower than the fifteenth moving toward the west and west-northwest, the director of the Hongkong Observatory says that their number only reaches 3 per cent. Now it so happened that solely during the four years of 1895–1898 we have registered ten baguios of this type, or, in other words, 11 per cent of the number set forth in the quoted pamphlet.

Probable limits of the zone of formation of cyclones originating in the Pacific.—Cyclones which originate more to the east of the Marianas and hence are dangerous for those islands, occur chiefly in the months of October and April, that is, in the months of the first and second group.

Exceptions.—Origin or formation of the baguio of the 1st to 6th of August, 1899.—These zones of formation of the cyclones of the Pacific are no more than probable, applicable to the majority of cases; therefore in no wise is it opposed to this that now and then a cyclone should be registered outside these indicated limits. Thus, for example, the typhoon of the 1st to 6th of August of the year 1899, although formed to the west of the Marianas, as is assured by observations in our possession made in those islands, appeared to have its origin to the west of the one hundred and thirty-ninth meridian east of Greenwich. This is clearly shown from the short record given of the cyclone in the monthly leaflet of the said month of August, in which, among other things, the following was stated:

> At 6 p. m. of the 31st of July the Observatory commenced to indicate a change of weather with this extraordinary notice:
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> "The barometer has commenced to fall slightly; weather unsettled." At 10 o'clock the following morning it announced to the public, to the coast of China and of Japan the existence of a depression to the east of Luzon.

According to valuable observations made on board the U. S. S. *Solace* on her voyage from Guam to Manila, the cyclone on the 31st of July was to the north of the said steamer, not far from the one hundred and fortieth meridian east of Greenwich, and probably between the fifteenth and seventeenth parallels, a distance from Manila of some thousand miles.

The cited observations made on board the steamship *Solace* are as follows:

EXTRACT FROM THE LOG OF THE U. S. S. SOLACE, GUAM TO MANILA.

Month and day.	Position.				Barometer.	Winds.		Remarks.
	Longitude (east).		Latitude (north).			Direction.	Force.	
	°	′	°	′				
July 31	140	03	12	44	29. 69	SW. by S.	3–5	Cloudy, squally, gentle to very fresh breeze in puffs, WSW. to SW. by S.
Aug. 1	138	20	11	11	29. 64	SSW.	6–8	Overcast, squally; fresh breeze to moderate gale from SSW. Rough sea from SW.
Aug. 2	136	30	11	14	29. 73	SW.	7–8	Overcast and cloudy, with passing showers; fresh breeze, increasing strong gale in heavy squalls.
Aug. 3	133	43	11	46	29. 76	SSW.	6–8	Cloudy and squally with passing showers; moderate gale, squally.
Aug. 4	130	44	12	42	29. 83	SW.	5–6	Clearing somewhat, stiff to fresh SW. breeze. Longitude SW. by seas.

These barometer readings are between 0.08 and 0.16 too high; the error being not exactly known.

On the 3d the observatory sent this other warning to the coasts of China, indicating the trajectory of the cyclone: "Third day, 7 p. m. The typhoon in the Pacific seems to be east-northeast of Manila between the eighteenth and twentieth parallels, moving probably to west-northwest or northwest."

As a matter of fact the cyclone continued moving toward the west-northwest or northwest by west, reaching the continent during the night of the 5th to the 6th.

WORKS WHICH MAY BE CONSULTED IN CONNECTION WITH CHAPTER II.

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CHAPTER III. STRUCTURE OF CYCLONES; OR, THE LAWS OF CYCLONIC CIRCULATION.

General idea of cyclonic circulation or of the motion of air in cyclones.—The form of the motion of air in cyclones is complex and is usually termed vorticose. We shall devote special attention to this motion in this chapter, taking into consideration the motion of the air at different heights in a cyclonic storm. Generally speaking the vorticose motion arises when more or less violent actions occur over an area or center of disturbance.

> Thus, for example [says Elliott[1]], when a very large forest is on fire the heated air over it rises, and the air flows in toward it from all sides. The air which rises up after it reaches a certain height tends to spread out and to move away in all directions. For reasons which are partly explained below, the inflow near the surface of the earth to the heated area does not take place directly, but by a species of spiral or revolving motion, forming whirls, such as are very common in water motion, even on the smallest scale. The air is in such a motion drawn in to the center, but not directly. It moves round the center of the disturbance and at the same time moves toward the central area into which it is drawn, and passes upward. Hence, when such a disturbance is started, the air at and near the earth's surface rushes toward the center from all directions, and the actual motion which results from such a rush toward a central area of disturbance and uptake is always rotatory. In the case of very small whirls such as give rise to waterspouts at sea, the whirling or rotatory motion is probably due to the fact that the air from different directions rushes in with slightly different velocities or rates of motion. In the case of the enormous whirls which form cyclonic storms this is not the chief cause in operation. This is due to the fact that the air is connected with the earth, which is a moving body. Hence, when the air is in apparent motion, it is actually moving with respect to a body which is itself in motion.
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> This introduces an important action which was only brought into full notice some years ago. Before starting it, it will perhaps be better to give an illustration. Suppose a person sitting or walking about in a train moving rapidly and that the motion of the train is suddenly altered by coming in collision with another train. The man would be by this change of motion suddenly thrown forward, and the effect, so far as the man in the carriage is concerned, is just the same as if he were impelled forward by a powerful force. This is only a particular case of a general principle. If two bodies are connected and moving with respect to each other, any change in the motion of the one will produce an effect on the other, which will be equivalent to the action of a force, and which may be more simply explained by assuming the existence of this equivalent force.
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> It is also evident that if the change is sudden, the equivalent force will be a sudden force, almost like a blow, whilst if it is gradual and continuous the force will be of the same character. Now, air, when it is moving over the earth's surface, is connected with, and moving with respect to, a body itself in motion. And, so far as one part of the earth's motion is concerned, viz, the motion round its axis once a day, the rate of motion differs at different parts of the earth's surface, being greatest at the equator and diminishing to nothing at the poles. It can be shown mathematically that the effect of the air moving over the earth's surface is almost exactly equivalent to the supposition that the earth is at rest and that there is a force which is always (in whatever direction the air may be moving) tending to turn it in the Northern Hemisphere to the right hand of its line of motion.

Let us now particularly consider the two most important laws of cyclonic movements.[2]

First—Cyclonic rotation.—The aerial currents in a cyclone form a great whirl around a comparatively small central space of calm, called the "vortex." The rotation always takes place in the same manner in the same hemisphere. In our own hemisphere the cyclonic rotation is invariably from right to left, and therefore in the direction from east to north, west, and south, or, as commonly expressed, in a direction contrary to that of the hands of a watch placed upon a horizontal plane, face upward. In the Southern Hemisphere the cyclonic rotation follows an opposite direction.

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[1] Handbook of Cyclonic Storms in the Bay of Bengal, Vol. I, p. 13, Calcutta, 1900.

[2] Viñes, *Investigaciones relativas á la Circulación y Traslación ciclónica en los Huracanes de las Antillas.* Habana, 1895, pp. 18–28. Investigation of the cyclonic circulation and the translatory movement of West Indian hurricanes. Washington, Weather Bureau, 1898, pp. 7–12. Bergholz, Die Orkane der Antillen. Marine-Rundschau, 1898, pp. 1613–1616.

Second—Cyclonic movements at different altitudes.—In the West Indian cyclones the cyclonic rotation takes place in such a manner that the lower currents converge as a rule more or less toward the vortex. At a certain altitude the currents follow a nearly circular course, and higher still their course becomes divergent. This divergence is all the greater, as the currents rise to higher altitudes, so that the highest *cirrus* clouds show in many instances a complete divergence; that is, they take a radial direction.

If the center of a cyclone lies due south, the wind will blow from east-northeast, the lowest clouds will move from east, the *alto-cumuli* from east-southeast, the dense *cirro-strati* from southeast, the *cirro-cumuli* from east-southeast, and the light *cirri* from south.

This succession of currents is in more or less completeness, an invariable occurrence in the West Indian cyclones, even when they present such an imperfect organization as to be considered simple cyclonic perturbations of slight intensity. It constitutes what is denominated "the law of cyclonic currents at different altitudes."

This law is of very great importance in the theory of cyclones. It is, however, not less useful for practical purposes, and for these it has much greater value than the so-called "law of storms." The latter takes the lowermost current, the wind only, into account and this, far from being circular as that law implies, is perhaps among all the cyclonic currents the element which forms the most variable angles, and is most affected by local influences and irregularities. On the contrary, the law of cyclonic currents at different altitudes takes into account all the currents in the various atmospheric strata within reach of observations, and by fixing the general convergence of the lowermost currents it improves the law of storms and gives it its real value. Through the gradation of the currents at different altitudes, which finds its expression in this law, the cyclonic movement is clearly laid down and brought together to a whole. The higher and intermediate currents can be relied upon with greater security and their direction can be determined with greater precision than that of the lower currents.

Before we proceed to a detailed examination of each of the cyclonic currents we wish to point out that the degree of convergence or divergence, constituting the gradation of the currents, generally varies not only in different cyclones, but also on the different sides of the same cyclone; that is to say, according as the cyclone is of greater or less diameter, of greater or less altitude, of greater or less intensity, of perfect organization or otherwise, according as the front or the rear of the storm is considered; or, finally, whether the vortex of the cyclone lies within the tropics or is notably distant from them. The convergence of the various currents differs also in the anterior portion of the whirl from that in the rear.

We publish the observations for each of these two general cases, and we take it for granted that the cyclone is situated between the tropics, or near them; that it is fully developed and displays a considerable force in its currents.

The anterior portion of the cyclone.—In the anterior portion (front) and on the side of the northerly winds of the cyclone, that is, of the winds from any direction between east, north, and west, the cyclonic currents are governed by the following laws:

Wind.—The winds converge as a rule toward the vortex, so that, supposing the observer stands with his face to the wind, the direction of the center of the storm (the bearing of the vortex) forms with the direction of the wind on the observer's right-hand side an angle greater than a right angle, embracing more than eight points of the compass.

In order to avoid unpleasant errors when determining the bearing of the center by using the direction of the wind, the following facts must be borne in mind:

(1) If the vortex lies at a greater distance and the cyclonic winds are not yet well developed, their convergence is apt to be greater and they are affected by many local influences and irregularities.

(2) The first squalls in front of the cyclone give divergent gusts; the squalls come, in fact, from the left-hand extremity of the cloud bank[1] and the gusts are directed outwardly. During such squalls the wind veers to the right accordingly, by four, six, and sometimes by eight, points.

(3) In the interior of the cyclone the gusts of the rain squall bring the wind always around to the right, tending, therefore, to lessen its convergence and sometimes almost to annul it.

(4) As the wind increases in violence in the neighborhood of the vortex, its direction becomes less convergent, owing to the centrifugal force developed in that part of the storm and probably, also, to the influence of the incessant squalls which in that part of the hurricane always occur.

(5) In Cuba the cyclonic winds from north to north-northeast exhibit scarcely any convergence. It is an acknowledged fact that the winds in front of the hurricane, in the first quadrant to the right, are less convergent.

(6) The trade wind, reënforced by the cyclone, modifies considerably the convergence of the cyclonic winds, sometimes completely suppressing it and at other times increasing it, so that the vortex may be lying to the south while the wind is from the northeast.

Rev. S. Chevalier, S. J., discusses this subject in his paper on "The Bokhára-Typhoon." He writes:

> Generally speaking, we may say that the bearing of the center of the typhoon is about 10 or 12 points from the direction of the wind; but that inclination varies with the position relatively to the center, and was stated by Pére Dechevrens to be somewhat greater in rear than in front. Doberck asserts that it is greater in higher than in lower latitudes. The same author says: "Once the wind has reached the force of a strong breeze, the average angle between the wind and the direction of the center does not appear to change at all; but the wind, blowing in great gusts in a typhoon, may oscillate on both sides of the mean value. There does not appear to be any foundation at all for the belief that the wind near the center blows in a circle round the center." I myself venture to say that both these assertions are incorrect.
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> That the angle of the direction of the wind with the radius vector changes with the distance has been proved in many investigations by Pére Dechevrens and by myself. But without going so far, a glance at the maps will show that at the more distant stations the angle is generally greater in the same direction.
>
> There is great difficulty in deciding the question as to whether the wind in the inner spirals has a circular motion, as Pére Dechevrens asserts, or not. When a station is very near the center of the typhoon, a small variation in the position of the center produces a great variation in the angle made by the wind with the radius of the typhoon. This angle can not, therefore, be determined accurately for those stations unless the bearing of the center be previously[2] determined with perfect exactness. But this exact determination is seldom possible. I dare not say that any position of the "Bokhara" typhoon has been determined so exactly as to be used in deciding the present question. In the study of the typhoons of the year 1892 I found two typhoons, the bearing of the center of which was determined with perfect exactness very near a meteorological station, and they have both shown the inner spirals in a typhoon to be circular round the center. The first was the typhoon which passed on the 17th of August between Turnabout and Middle Dog; the second the typhoon which passed over Tamsui during the night of the 6th of September.
>
> There is another circumstance which has a great influence on the direction of the wind, and to this great attention must be paid in determining the bearing of the center. That is the direction of the monsoon. In the neighborhood of Swatow the winds have an inward tendency which is far from being so great as at the northern stations of the Formosa Channel. We shall close this discussion with the rule above stated and now generally admitted. The center of a typhoon bears generally from 10 to 12 points from the direction of the wind; accordingly, with your back to the wind, you will have the center on your left, from 2 to 4 points ahead; but if the monsoon is blowing so as to reduce the angle with the *radius vector*, especially if you are still far from the center, you should allow at least 5 points ahead and still bear in mind that any such estimate is only a rough approximation.

(7) Islands and continents have a decided influence on the direction and veering of the wind. Rev. A. Froc, S. J., writes in a very recent work:[3]

> **Variations of the typhoon in shape and depth.**—The typhoon of August 3 is a striking instance of the modifications which a violent storm may undergo in the various phases of its existence. What was it in the first stage of its career, when, taking shape or, when, already well framed, it darted toward the barrier of islands strewed between Formosa and Japan, we have now no means of saying. To the north of Formosa, over

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[1] The face being turned toward the cloud bank.

[2] This determination must be arrived at previously and therefore independently of any supposed inclination of the wind to the isobars, and ought to be certain and accurate.

[3] The "De Witte" typhoon, August 1–6, 1901, p. 14–15.

those immense waste spaces where the cyclone could freely grow and spread itself, it appears in the shape of a mighty atmospheric depression, with level lines almost circular, surrounding an elliptical space of calm, stretching its greater axis from west to east, whilst it propagates itself in a body in the direction of west by north.

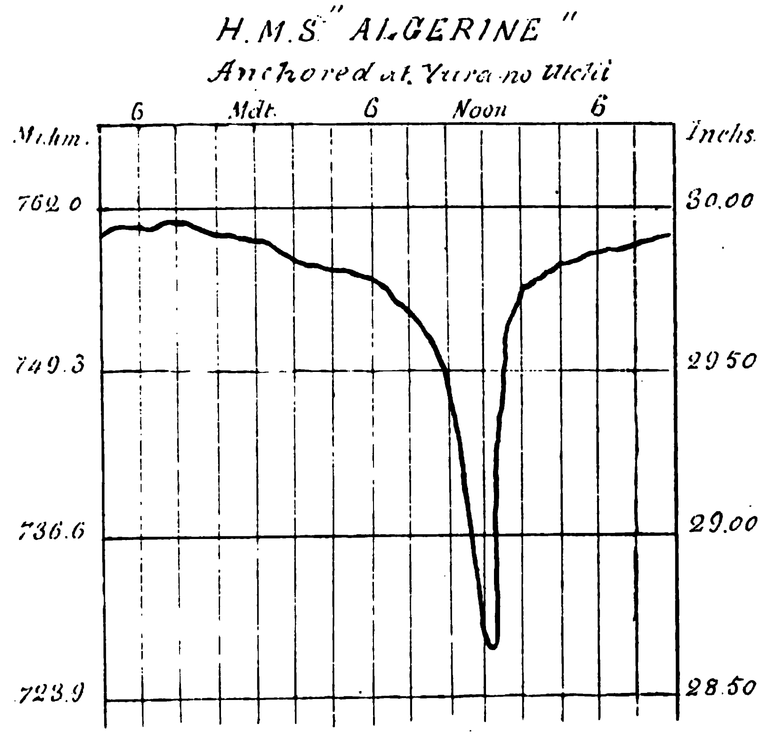
The existence of a centripetal component of the winds circulating within that immense disturbed space has been too well established over and over again to need being discussed here. We will only, as an instance, give the acute angle between the radius drawn from the observer to the center and the direction of the breeze, in various azimuths and at various distances, on the 2d, about midnight, at which hour the center was passing to the north of Keelung.

AUGUST 2 (MIDNIGHT).

Bearing of the center.	S.	SSE.	E.	ENE.	NNE.	N.	NW.	W.	SSW.
Distance (miles)	112.7	84.0	86.3	110.3	96.0	93.5	165.4	60.0	208.6
Angle of the wind with the bearing (degrees)	70	58	48	45	42	6	43	80	58

On the whole, it then appears that within the really intense part of the perturbation an observer, with his back to the breeze, had the center at 10 points on his left (port) if he was on the north of the center; at 11 points if he was on the south; at 11.5 points on the west and forward, and lastly at 9 points on the east and behind: all this in open sea, far from local perturbations of which we shall speak hereafter.

As soon as the phenomenon drew near the coast it underwent a rapid modification so as to make it unrecognizable. From the first the center filled up rapidly, so that the minimum, which had attained the depth of 686 mm. in the offing, had risen to 710 mm. in the proximity of land, and reached 730 mm. one day later, on the banks of the Yangtse-kiang. Another equally striking feature was the sudden suppression of the appendix in the shape of a chimney which seems to characterize the centers of true typhoons. The annexed figure shows this character in a very striking manner. It is the tracing left upon a Richard barograph by the typhoon of September 8, 1899, on board the English cruiser *Algerine* at Yura-no-Utchi, in the waters of the Kii Channel, not far to the south of Kobe and Osaka. This document, which we have not yet been able to utilize, was graciously communicated to us by the commander, C. J. Warre Stade, R. N. (On the passage of the cyclone the wind skipped from east by south force 12, to west by north force 12; the whole took less than twenty hours, and the true typhoon lasted only twelve hours; four hours after the minimum the breeze was from north-



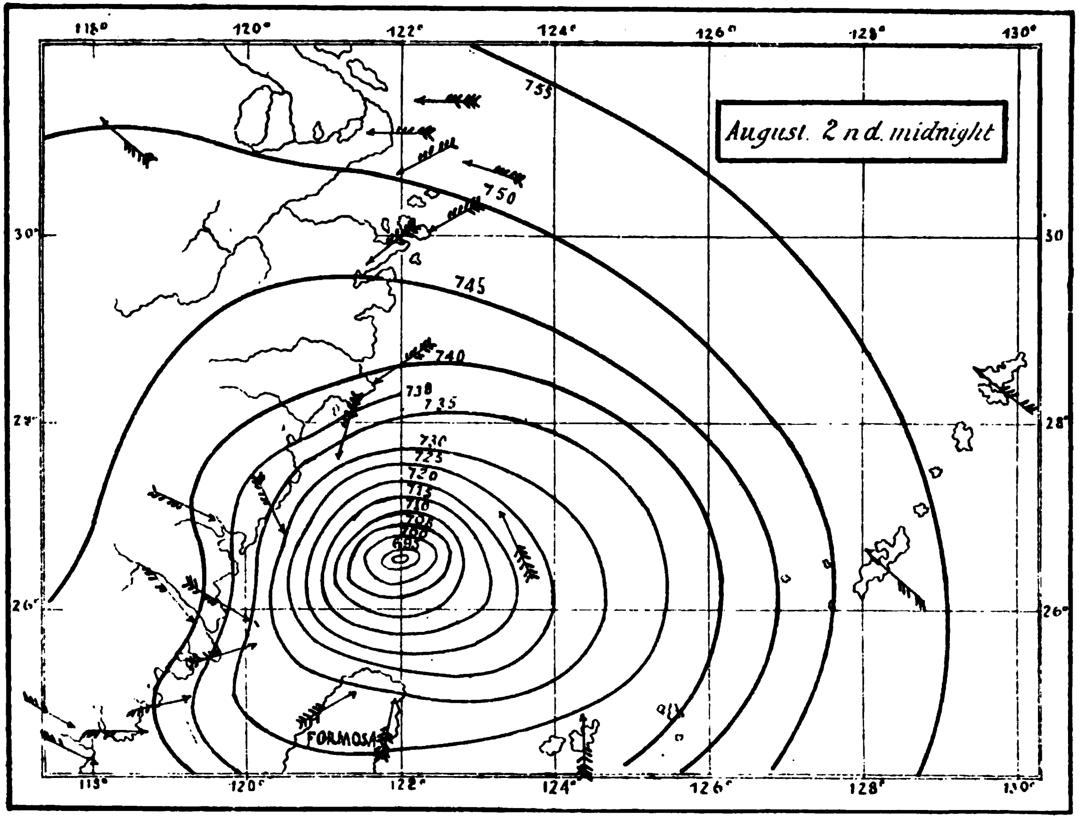
(Fig. 3.) Typhoon of September 8th. 1899.

> northwest force 2.) This tracing, made on a scale with which the multiplication of Richard's barographs has made most sailors familiar, is seen to represent almost exactly the shape of a funnel. A ship that passes far from the center will only have a bell-mouthed depression of greater or lesser depth, as would be the piece broken off by a sharp blow upon the side of a drinking glass. Such was the case for the *Surprise*, the *Phœnix*, and the *Bombay*. Nearer to the center the shape is that of a cone more or less acute according to circumstances; such were the curves of the *Descartes* and of the *Chiyuen*. At the center, a chimney or a sheath inclosing the calm comes to settle on the point of the cone, of greater or lesser width and depth, according to the degree of violence of the phenomenon. Such was the curve of the *Laisang;* such was also the elegant curve of the *Algerine*, which reproduced the other in miniature, though the result was in fact equally violent, as the energy of the typhoon had concentrated into a narrower space.
>
> On reaching China, the appendix of the typhoon of August 3 became suppressed, and the barograms, even nearest to the center, as on board the *Lion*, the *Tung-chow*, the *Bengali*, and even the *Chasseloup-Laubat*, in lieu of the typical funnel, show now nothing but wide-mouthed basins or cups with gently sloping sides; the violent effects of the center are then suppressed.

(8) The deformation of the isobars and the subsequent veering of the wind is also a noticeable fact whenever the cyclone reaches land. Rev. A. Froc, S. J., writes again:[1]

> Let us also carefully notice the deformation of the isobars. It appears in fig. 4 that, on meeting with the denser and dryer atmospheric layers of the continent, not yet completely shaken, the elastic body of the typhoon, whose foot pressed against a kind of wall of high hills, experienced a true knock, and the foremost air waves pushed obliquely against these obstacles, seem to have fallen back—a kind of aerial recoil or surf.

(Fig. 4.) THE "DE WITTE" TYPHOON, 1901



> There ensued a compression on the force part of the cyclone, whose isobars are seen to flatten, to draw closer together and even to hollow out to the east in curves parallel to the coast, with their convexity toward the center, which is approaching, whilst the fall spreads out more freely toward the southwest, over the less obstructed spaces of the Formosa Channel. This shock of the first violent spires of the phenomenon against the aerial mountains and layers of the continent seems to have exerted a decisive influence upon the modifications undergone by the typhoon in its constitution and in its progress. It was in going to meet those back

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[1] The "De Witte Typhoon," p. 15.

waves, seats of powerful condensations, that the center was seen to fill up, and its level rise gradually in few hours from 685 mm. to 710 mm.

It was also this flattening undergone by the external isobars which communicated itself gradually to the whole body of the typhoon, up to the central nucleus, so as to turn the whole by degrees toward the northwest and the north-northwest in the shape of very elongated ellipses which, owing to their elasticity, rebounded and darted in a lump in the direction of the great lakes on the right bank of the Blue River.

This reflux consequent upon the first shock also seems to explain the fact of a great deep atmospheric wave, clearly traced upon the registering barometers of the *Descartes*, of the *Surprise*, and others, and which gave the signal for the beginning of bad weather. This bend in the registering, which might be called *the typhoon's wrinkle*,[1] is but a phenomenon which we have already signaled and circumstantially described in a paper upon the great, violent typhoon of September 9, 1897. There the subject was a powerful cyclone, which came obliquely to strike the mountainous coast of Japan between the heights of Shikoku and the foot of Mount Fujiyama, before bending to east-northeast, ready to fall upon Tôkiô. An atmospheric wave, analogous to that in question, took place upon all the force part of the phenomenon; it was registered on board the *Yarra* and of the *Empress of India*, and was the seat of electric phenomena of great intensity. In the present case there is a remark which comes to strengthen the explanation we deem having found of the fact, viz, in a compression resulting from an interference between the waves of the typhoon advancing from the offing and a back wave: that compression, indicated by the sudden rise of the barometer, must have been accompanied with emission of heat. Now, with regard to the violent squall signaled at this very moment, the *Descartes* reports expressly that "puffs of a scorching wind coming from the north passed over the ships before the squall, which brought very little rain."[2]

(9) Marked inclination of the axis of a typhoon in approaching the coast. Rev. Froc, S. J., says:

Lastly we believe that an effect of this shock between masses of air of various densities, at the time of coming to land, was to give the axis of the whirlwind a marked inclination, at first backward, and afterward to the right of the trajectory, when the center of the phenomenon ran toward north-northwest, as if the head of the cyclone tended to remain as long as possible close to the surface of the sea, which supplied the food for its energy, the vapor of water.

That inclination was mostly manifestly by two principal effects, the first of which was the rapidity of the rise on board the two ships placed on both sides of the trajectory, very near the center, viz, the *Descartes* and the *Chiyuen*. On board the latter, the fall, during the two hours which preceded the minimum, had been of 14 mm. in round numbers, whilst two hours after the central calm the pressure had risen again by 20 mm.; that is 6 mm. more. On board the French cruiser the same intervals gave 9 mm. and 14 mm., respectively, or 5 mm. in favor of the rise. In the offing, on the contrary, on board the *Laisang*, the advantage seems to have been in favor of the fall. The complete filling up of the typhoon may have affected the rise of the pressure, but not to that degree, and we may be allowed to think that the inclination of the axis must be called in to complete the explanation. In fact let us suppose that the axis of rotation of the aerial spires comes to lean backward at the moment when the center passes in the neighborhood of a station. The air, continuing to turn in planes almost perpendicular to the axis, will become very perceptibly dipping instead of ascending at least from a certain height, and since the effect of this movement is to press upon the lower layers, it will naturally bring about an acceleration in the rise of the pressure. This dipping rotation will also bring about the second effect we mentioned, viz, that of which Rev. Father Algué, Director of the Manila Observatory, treated in his important work upon the tropical storms.[3]

The side toward which this dipping will take place will really be the *violent* side, not to say the *dangerous* side—an expression to which another meaning has been given. There in fact the wind, striking the ground, and above all lashing the surface of the sea, will exert a more direct action to perform its work of destruction or toss the sea into waves of greater depth. Now, as we have already said, the action of the typhoon made itself felt particularly upon the right, and abaft of the center in motion, so that, before we had received the document of the *Chasseloup-Laubat*, we should have made the center cross the Yang-tse-kiang much nearer to Wu-hu. As for the effect produced on the sea, we refer to the report of ships particularly of the *Phœnix* and of the *Lion*, as well as to the enormous swell from southwest, noticed by the latter in the Gulf of Pechili, at a time when the foot of the axis of the typhoon must long since have passed into the west, as explained before.

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[1] This movement (*le pli du typhon*) in front of the meteor, is not without analogy with the solitary wave (*la vague solitaire*) of Scott Russel, preceding the passage of a vessel, at a given distance, in a narrowly embanked channel.

[2] See Shanghai Met. Soc. Reports for the years 1896 and 1897. The typhoons of September 9 and 29, 1897, by Aloys Froc, director of Zi-ka-wei Observatory, p. 12. The southeast side of the trees burned at Zi-ka-wei by the wind did not recover all the summer.

[3] See the work of the author published at the Manila Observatory in Spanish (1897), or the French translation in the Annales Hydrographiques, série 2, Volume de 1899, No. 808.

Lower clouds.—The low clouds move in a direction nearly perpendicular to the bearing of the vortex. The motions of the clouds exhibit much greater regularity than the direction of the wind and this offers us, therefore, a certain clue in order to find the center. The lower clouds include the heavy, low *cumuli* of dark or leaden hue, the *strato-cumuli* and *fracto-nimbi,* which in the interior of the whirl move with great velocity. The fracto-cumuli which appear at the commencement are higher and less dense. They are not unlikely to show some divergence.

As a practical result of the observations made in this Observatory, we present the following table, in which we have included the typhoons that, in the period from 1880 to 1902, have influenced Manila with a barometric minimum of less than 753 millimeters (29.65 inches), indicating in the respective columns the position of the storm center with respect to Manila at the hour of the minimum, the direction of the wind and low clouds observed in the observatory at that hour, and the angle formed by said directions and the position of the vortex:[1]

Date.	Hour.	Barometric minimum.		Zone.	Bearing of vortex at time of minimum.	Wind direction at time of minimum.	Angle between wind direction and bearing of vortex.	Direction of low clouds at time of minimum.	Angle between direction of low clouds and bearing of vortex.
		Millimeters.	Inches.						
1880.							°		°
Sept. 21	3.00 p. m.	749.97	29.527	B.	N. by E.	SW.	146	--------	-----
1881.									
May 24	1.30 p. m.	49.29	.500	B.	SW.	E. by S.	124	SE.	90
June 28	8.00 p. m.	49.49	.508	B.	NE. by E.	W. by N.	135	--------	-----
July 13	4.00 p. m.	51.26	.578	A.	NE.	WSW.	158	W.	135
Aug. 19	8.00 p. m.	49.34	.506	B.	ENE.	WSW.	180	N.	68
Sept. 6	4.00 p. m.	52.89	.642	A.	N. by E.	WSW.	124	W.	101
Oct. 12	7.00 p. m.	52.38	.622	A.	NE.	SW.	180	WSW.	158
Oct. 20	4.00 a. m.	49.21	.497	B	N.	WSW.	113	WSW.	113
Dec. 12	5.00 a. m.	51.55	.589	A.	S.	N.	180	E.	90
1882.									
Sept. 9	4.00 p. m.	52.68	.634	A.	NE. by N.	WSW.	146	WSW.	146
Oct. 20	11.50 a. m.	27.76	28.652	D.	N.	WSW.	113	WSW.	113
Nov. 5	10.20 a. m.	35.62	28.961	D.	S.	NNE.	158	WSW.	68
1883.									
July 10	5.00 p. m.	50.67	29.554	A.	NNE.	SW.	158	WNW.	90
Oct. 28	12.00 p. m.	48.57	.471	B.	SW.	ESE.	113	WNW.	68
Nov. 17	3.00 p. m.	52.89	.641	A.	SSW.	E.	113	E.	113
1884.									
July 10	4.00 p. m.	50.24	.537	B.	NNE.	SW.	158	WSW.	135
July 27	2.00 p. m.	49.71	.516	B.	N.	SW.	135	--------	-----
Aug. 20	4.00 p. m.	50.09	.531	B.	N.	SW.	135	WSW.	113
Nov. 18	10.00 a. m.	47.78	.440	B.	N.	WSW.	113	--------	-----
1885.									
Aug. 23	3.00 p. m.	52.53	.627	A.	NE. by N.	W. by S.	135	NW.	79
Nov. 7	4.30 p. m.	48.69	.476	B.	ENE.	WNW.	135	NNW.	90
1887.									
Sept. 10	4.00 a. m.	49.25	.498	B.	NNE.	SW.	158	NNW.	45
Sept. 19	3.00 p. m.	48.01	.449	B.	N.	SSW.	158	--------	-----
Sept. 24	3.00 p. m.	48.39	.464	B.	N.	WSW.	113	W.	90
Sept. 30	3.00 p. m.	52.73	.635	A.	NW.	SSW.	113	SW.	90
1888.									
July 14	3.00 a. m.	47.62	.434	B.	N. by E.	SW.	146	WSW.	124
Sept. 27	5.00 a. m.	51.16	.573	A.	N.	WSW.	113	WSW.	113
1889.									
July 16	3.00 a. m.	52.13	.611	A.	NW.	SSE.	158	SW.	90
Oct. 29	2.00 p. m.	51.03	.568	B.	SSW.	NNE.	180	ESE.	90

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[1] We have omitted those cases in which two centers of depression have influenced Manila at the same time or other complications have been observed in the atmosphere difficult to explain.

Date.	Hour.	Barometric minimum.		Zone.	Bearing of vortex at time of minimum.	Wind direction at time of minimum.	Angle between wind direction and bearing of vortex.	Direction of low clouds at time of minimum.	Angle between direction of low clouds and bearing of vortex.
		Millimeters.	Inches.						
1890.							°		°
Sept. 5	4.00 p. m.	752.40	29.622	A.	N.	SW.	135	W.	90
Sept. 30	1.50 a. m.	47.12	.414	B.	N.	SSW.	158	------	------
Oct. 1	2.35 p. m.	52.02	.607	A.	NE.	SW.	180	------	------
Nov. 11	12.50 p. m.	43.51	.272	C.	N.	SW.	135	------	------
1891.									
Nov. 13	5.11 p. m.	50.83	.560	B.	SSE.	NNW.	180	NE.	113
1892.									
Nov. 16	8.20 a. m.	48.52	.469	B.	S.	N.	180	NE.	135
Oct. 9	4.45 a. m.	49.81	.520	B.	NE.	WSW.	158	NW.	90
Oct. 28	2.03 p. m.	53.11	.650	A.	NE.	SW.	180	WSW.	158
Nov. 21	2.12 p. m.	49.13	.493	B.	ENE.	NW. by N.	101	------	------
1893.									
May 15	3.00 a. m.	46.20	.378	C.	SE. by E.	N.	124	------	------
Sept. 1	3.00 p. m.	53.01	.646	A.	NNE.	SSW.	180	WSW.	135
Sept. 26	3.45 p. m.	50.24	.537	B.	NNE.	SW.	158	WSW.	135
Sept. 30	4.11 p. m.	46.45	.388	C.	N. by E.	SW.	146	W.	101
1894.									
Sept. 17	3.00 a. m.	42.37	.227	C.	N.	SSW.	158	SW.	135
Sept. 28	1.36 a. m.	45.52	.355	C.	E. by N.	NW. by N.	113	------	------
Oct. 3	2.05 a. m.	48.03	.450	B.	NNE.	WSW.	135	------	------
1895.									
Sept. 3	2.55 p. m.	52.18	.613	A.	NNE.	SW.	158	W.	113
1896.									
May 17	2.25 p. m.	51.11	.571	A.	N. by W.	SW.	124	WSW.	101
June 6	3.00 p. m.	51.67	.593	A.	SW.	E.	135	SE.	90
July 22	3.40 a. m.	51.92	.603	A.	NE. by N.	SW.	169	------	------
July 28	2.20 a. m.	50.62	.552	B.	NE. by N.	WSW.	146	------	------
Aug. 8	4.50 a. m.	50.24	.537	B.	N.	SW. by W.	124	------	------
Oct. 4	6.35 a. m.	50.37	.542	B.	N.	W. by S.	101	W.	90
Oct. 9	3.40 p. m.	51.11	.571	A.	NNE.	WSW.	135	W. by N.	101
1897.									
Aug. 8	4.20 p. m.	52.58	.629	A.	NNE.	SSW.	180	SW. by W.	146
Oct. 13	5.00 a. m.	51.87	.601	A.	S. by W.	NNE.	169	E. by S.	90
1898.									
Mar. 15	3.15 p. m.	53.01	.646	A.	W.	SE.	146	S. by W.	90
May 31	3.00 p. m.	50.86	.561	B.	NE. by N.	W. by S.	135	W.	124
Aug. 1	2.25 a. m.	50.72	.556	B.	------	Calm.	-	------	------
Aug. 4	3.00 p. m.	52.40	.622	A.	NNE.	SW. by W.	146	------	------
Aug. 16	3.00 a. m.	52.65	.632	A.	------	------	------	------	------
Oct. 25	4.00 a. m.	57.87	.601	A.	NNW.	SSW.	135	------	------
Nov. 12	3.10 p. m.	47.02	.410	B.–C.	N. by E.	S. by W.	180	SW. by S.	158
1899.									
May 23	3.05 p. m.	52.96	.644	A.	W.	SE.	135	SE. by S.	124
June 28	4.00 p. m.	52.35	.620	A.	------	SW. by W.	------	WNW.	------
July 5	4.00 p. m.	51.53	.588	A.	NNE.	SW.	158	W.	112
July 18	3.00 p. m.	52.86	.640	A.	NE. by E.	NW.	101	W.	146
Aug. 4	4.25 p. m.	51.46	.585	A.	NNE.	WSW.	135	W.	112
Sept. 20	3.20 p. m.	51.33	.580	A.	N.	SW.	135	SW.	135
Nov. 15	3.00 a. m.	51.82	.599	A.	------	W.	------	------	------
1900.									
Aug. 14	3.40 p. m.	51.06	.569	A.–B.	N. by E.	SW. by W.	135	SW. by W.	135
Aug. 19	4.25 a. m.	51.62	.591	A.	NNE.	SW. by W.	146	------	------
Sept. 8	4.20 p. m.	45.75	.390	C.	N.	SW. by S.	146	SSW.	157
Nov. 1	1.50 p. m.	49.38	.503	B.	SW.	E.	135	E. by S.	124
Nov. 6	1.50 p. m.	51.06	.591	A.	SE.	N.	135	E.	45

Date.	Hour.	Barometric minimum.		Zone.	Bearing of vortex at time of minimum.	Wind direction at time of minimum.	Angle between wind direction and bearing of vortex.	Direction of low clouds at time of minimum.	Angle between direction of low clouds and bearing of vortex.
		Millimeters.	Inches.						
1901.							°		°
July 22	2.30 p. m.	752.96	29.644	A.	N. by W.	SW.	124	------	------
Aug. 23	3.55 p. m.	52.48	.625	A.	NNE.	WSW.	135	SW. by W.	------
Oct. 3	3.40 a. m.	49.38	.503	B.	NNW.	SSW.	135	------	------
Oct. 14	7.05 p. m.	48.37	.463	B.	N. by E.	WSW.	124	------	------
Oct. 23	1.20 a. m.	51.51	.587	A.	N. by E.	WSW.	124	------	------
1902.									
June 1	3.00 p. m.	52.38	.621	A.	------	W.	------	------	------
July 26	2.05 p. m.	46.60	.394	C.	NNW.	SW. by W.	101	WSW.	90

A few of the lessons taught by the foregoing catalogue.—If we regard the average which this table gives us for the angle that the winds and the low clouds form with the bearing of the storm center, we shall see that it agrees pretty well with the law for these currents in the posterior part of the cyclone indicated by Father Viñes. But if we carefully examine each particular case we shall doubtless find very different angles, very slight convergence being sometimes noted even with winds of the posterior part, and at other times, on the contrary, a maximum convergence. This being so, it occurs to us to ask whether this same thing will happen in the whole Archipelago, and what may be the cause of this diversity. This we think we can answer by saying that probably in each locality it will be noted after careful study that some of the winds are usually more or less convergent than others, the degree of convergence depending on the different topographical conditions. Hence it may very well be that the winds which are generally most convergent in Manila are the least convergent at other points of the Islands, and vice versa, which we could easily prove by discussing the winds observed in other stations of Luzon at the time of the barometric minima. But it would make the present investigation too long, and so we content ourselves with offering this suggestion, which is of the greatest importance, lest we expect the same convergence of winds everywhere; for we see that this may be modified by the topographical conditions of each locality. Moreover, it causes us to understand that the laws of Father Viñes for cyclonic circulation do more fully apply to the high seas than to land, because there the winds can blow without meeting obstacles of any kind.

MOST CONVERGENT WINDS IN MANILA.

Now, which are the most and which the least convergent winds in Manila? For this, and only considering the cases included in table on pages 33–35, we have taken separately the winds comprised between north-northwest and northeast, the northwest by north and west by northwest, the west and south-southwest, and the east and southeast, finding the mean of the angle corresponding to each one of these four groups. The result obtained is the following:

Winds.	Number of cases.	Mean angles (degrees).[1]
NE. to NNW	8	161
NW. by N. to W. by N	5	116
W. to SSW	54	143
E. to SE	6	140

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[1] By "mean angles" are meant the means of the angles formed by the directions of the wind and the radius vector.

The greatest convergence at the time of the barometric minimum corresponds to the winds from the north quarter and the least to the winds from the east quarter. It must be borne in mind that we say "at the time of the barometric minimum"; for, generally speaking, a long experience teaches us that the most convergent winds are those of the third quadrant and therefore, taken absolutely, the said proposition would be entirely false. But limiting ourselves to the time of the minimum, it is very true, and we see it verified by innumerable examples; for we have seen that when a typhoon passes toward the south and near Manila the winds blow from the north and north-northwest for the space of one or two days in such a fixed manner that they only incline toward the east when the vortex is passing, or has already passed, the meridian of the capital, as if an obstacle—which may be the great mountain ranges of eastern Luzon—prevented the free circulation of the winds from the northeast and east-northeast. And in these cases it is seen that the weather vane having remained fixed in the north or north-northeast so long, still it veers toward the east and east-southeast and southeast afterward in the course of very few hours, the convergence of these winds in these cases being generally very slight, notwithstanding that they belong to the posterior part of the cyclone. Therefore it appears that the valleys of the Island deflect in Manila the cyclonic winds to the north and north-northwest before the typhoon passes by the south, and to the east and east-southeast immediately after it has passed our meridian.

The convergence of the winds of the third quadrant, provided a cyclonic storm center is passing toward the northeast or north of Manila, is generally very extraordinary; so much so that these winds are frequently wholly convergent.

Intermediate clouds.—The *alto-cumuli,* the dense *alto-strati,* and the light *cirro-cumuli,* move from divergent directions, forming with the bearing of the vortex acute angles that are smaller in proportion as the currents to which they belong occupy a higher position; that is to say, the smallest angle is formed by the *cirro-cumuli* and the greatest by the *alto-cumuli.*

The angles which these currents form with one another and with the radius vector, are far from being constant. Their magnitude depends on the more or less complete separation of the various strata, on the regularity in their distribution, on the degree of development of the cyclone, on the greater or less altitude, and on the activity of the whirl. In a well-developed cyclone of considerable intensity a great regularity will be observed as to the distribution of the strata and the magnitude of the angle in question. The angles in such cases are of the following magnitudes, approximately: For the *alto-cumulus,* 6 points; for the *alto-stratus,* 4 points; and for the *cirro-cumulus,* 2 points.

High clouds—Cirrus.—The highest of all cloud-forms, the light *cirrus* clouds, move as a rule in a completely divergent or radial direction, forming with the bearing of the vortex an angle equal to zero, or practically inappreciable. The current at the altitude of the *cirrus* clouds is the most regular, forming a right angle with that of the low clouds.

To sum up briefly, we find that the cyclonic currents which exhibit the greatest regularity and point out best the bearing of the vortex are those of the *cirrus* and the low clouds. The current of the *cirrus* clouds is that which should be selected in preference when the first indications of the approach of a cyclone are seen and the vortex is still far distant. In the interior of a storm the observer must be guided principally by the movement of the lower clouds. In the absence of *cirrus* clouds the currents of the *cirro-cumulus* and *alto-stratus* may guide him; and when there are no lower clouds, the wind and the high cumulus may be resorted to instead; always bearing in mind, however, that these indications as to the bearing of the center are less reliable and the approximate inferences less satisfactory. In a well-developed cyclone of considerable intensity whose center is south-southeast, the *cirrus* clouds will move from south-southeast, *cirro-cumlus* from southeast, the dense *cirrus-veil* from east-southeast, the *alto-cumulus* from east, the low clouds from east-northeast, and the wind from northeast.

The rear of the cyclone.—In the rear of the cyclone, and in general when the prevailing winds are from the south, or from the points of the compass between east-southeast, south, and west-southwest, it is observed that all the currents in general form wider angles with the bearing of the vortex than in the previous case, the gradation between them, however, remaining the same; so that in the rear of the storm the inferior currents are more convergent and the superior ones more divergent that in the front. Thus, for example, if the vortex lies to the northwest, the wind comes from south-southeast or south, the low clouds from south or south-southwest, the *alto-cumuli* from southwest, the *cirro-strati* from west-southwest, the *cirro-cumuli* from west, and the *cirri* approximately from west-northwest.

Cyclones in the middle latitudes.—As the cyclone moves to the north of the Tropics and is converted into a cyclone of the middle latitudes the currents gradually lose their regularity, although their gradation continues much the same. Sometimes, however, the movements of *cirrus* clouds present great irregularities; when, for example, in the Gulf States the vortex lies to the northwest or north-northwest, the current of the *cirrus* clouds is apt to come suddenly from the northeast.

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CHAPTER IV. MOVEMENT OF THE BAROMETER DURING CYCLONES.

There is an intimate connection between the mechanism, structure, and we might say, the organism, of a cyclone on the one hand and the movement of the barometer on the other, wherefore we intend to treat of the movements of the latter in this chapter with a care in proportion to its importance.

The laws of the daily oscillation of the barometer.—Before entering on the study of the movements of the barometer during cyclones it will not be out of place to give briefly a few facts relative to the state of atmospheric pressure, so generally observed and so universally admitted, which constitute what we may call the laws of the normal movements of the barometer.

(1) Atmospheric pressure shows in its daily movement two maxima and two minima.

(2) Generally speaking, we may consider the morning maximum and the afternoon minimum as being the absolute maxima and minima.

(3) In the Tropics the hours for the daily maximum and minimum vary slightly with the stations. On account of the position of the sun the afternoon minimum occurs usually at 3 o'clock during September, October, November, December, January, and February, but during the other months at 4 o'clock.

(4) The amplitude of the oscillation of the day period and the night period also varies with the station. By day period we understand that comprehended between the maximum of the morning and the minimum of the afternoon, and by night period that between the maximum of the night and the minimum of early morning.

(5) The amplitude is usually greater during the daytime than at night.

(6) The amplitude of the daily movement of the atmospheric pressure depends on the geographical latitude. It is greatest at the equator, about 3 millimeters (0.12 inch), and decreases towards the poles.

(7) The amplitude is usually greater on land than at sea, being likewise greater in mountainous countries than over extensive plains.

(8) With regard to the influence which the height of the place of observation exercises, it can be said that the amplitude decreases with the height; and that the daily movement at a great altitude seems to be contrary to that on a plain.

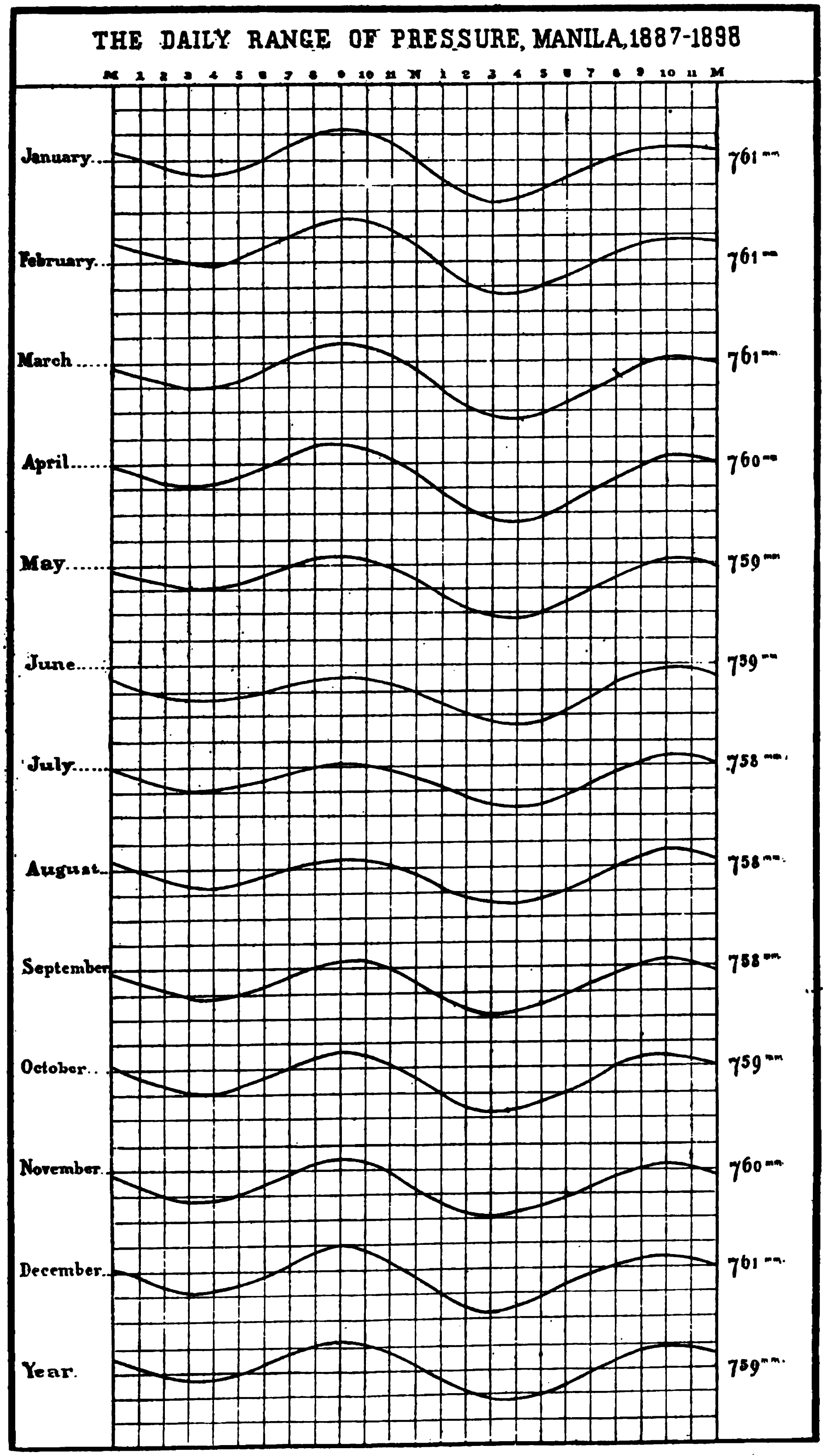
The normal height of the column of mercury also depends on the latitude and the geographical position. By the normal height of the barometer is understood the mean height corresponding to a certain period of time reduced to 0° C., and the level of the sea and corrected, if necessary, for gravity. (See Pl. XV.)

Annual variation of the barometer.—Besides the daily oscillation of the barometer, there is also an annual variation which likewise depends on the latitude and geographical conditions. In general we may say that the larger the daily oscillation, the smaller is the annual, and vice-versa.

Knowing the normal movements of the barometer, we pass on to the abnormal movements which are observed during great atmospheric disturbances.

Importance of the laws of the daily oscillation of the barometer.—A careful study of the daily course of the atmospheric pressure in the Philippines must, without doubt, be of the greatest

Plate III.



THE DAILY RANGE OF PRESSURE, MANILA, 1887-1898

UNIV. OF MICH.

importance, not only for the better knowledge of the climate of these Islands, but mainly to be able to know several days in advance of the existence of a cyclone or typhoon, and to seek protection from its fearful effects. The daily oscillation of the barometer is so regular in these latitudes that we have seen it rightly compared by some authors to the movements of a clock; and it may be said with certainty that the least irregularities observed in it are generally the most unmistakable indications of the proximity of some atmospheric disturbance. When we speak further on of the cyclones in the Far East, it will be seen that the rules which worthy Father Faura gave for the right use of his popular barometer are based, in a great measure at least, on the laws which govern the daily oscillation of atmospheric pressure in normal weather or when there is no noticeable change in the atmosphere.

The hourly means of atmospheric pressure compared with each other and with the monthly means.—In order to fully confirm the laws which, as we have seen in the preceding paragraph, govern the daily oscillation of the barometer in Manila, and in order to deduce some others which are of no less importance, we give the following table. The same contains two sets of differences distinguished by different types. The numbers in larger print are the mean differences between the means of the barometric readings for each hour of the day and night and the mean of the atmospheric pressure of the month (in the sense, mean hourly reading minus monthly mean), while the numbers in smaller print exhibit, as auxiliary data, the mean values of the ascent or descent between each of the twenty-four hours and the one immediately preceding it.

DIFFERENCES BETWEEN THE HOURLY MEANS AND THE MONTHLY MEANS AND BETWEEN THE SAME HOURLY MEANS COMPARED WITH EACH OTHER.

I. METRIC SYSTEM.

Hour.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1 a. m	**0.16**	**0.18**	**0.25**	**0.31**	**0.26**	**0.28**	**0.21**	**0.25**	**0.17**	**0.05**	**0.08**	**0.14**	**0.20**
0-1 a. m	— 0.27	— 0.30	0.32	— 0.25	— 0.33	— 0.40	— 0.39	— 0.37	— 0.35	— 0.46	— 0.36	— 0.23	— 0.33
2 a. m	**— 0.17**	**— 0.13**	**— 0.09**	**— 0.04**	**— 0.06**	**— 0.03**	**— 0.12**	**— 0.12**	**— 0.18**	**— 0.28**	**— 0.30**	**— 0.24**	**— 0.15**
1-2 a. m	— 0.33	— 0.31	— 0.34	— 0.35	— 0.32	— 0.31	— 0.33	— 0.37	— 0.35	— 0.33	— 0.38	— 0.38	— 0.35
3 a. m	**— 0.43**	**— 0.36**	**— 0.29**	**— 0.27**	**— 0.26**	**— 0.22**	**— 0.32**	**— 0.36**	**— 0.41**	**— 0.48**	**— 0.55**	**— 0.51**	**— 0.37**
2-3 a. m	— 0.26	— 0.23	— 0.20	— 0.23	— 0.20	— 0.19	— 0.20	— 0.24	— 0.23	— 0.20	— 0.25	— 0.27	— 0.22
4 a. m	**— 0.40**	**— 0.36**	**— 0.33**	**— 0.25**	**— 0.25**	**— 0.27**	**— 0.38**	**— 0.40**	**— 0.47**	**— 0.52**	**— 0.55**	**— 0.46**	**— 0.39**
3-4 a. m	0.03	0.00	— 0.04	0.02	0.01	— 0.05	— 0.06	— 0.04	— 0.06	— 0.04	0.00	0.05	— 0.02
5 a. m	**— 0.19**	**— 0.14**	**— 0.12**	**0.01**	**— 0.07**	**— 0.16**	**— 0.30**	**— 0.31**	**— 0.31**	**— 0.34**	**— 0.33**	**— 0.25**	**— 0.21**
4-5 a. m	0.21	0.22	0.21	0.26	0.18	0.11	0.08	0.09	0.16	0.18	0.22	0.21	0.18
6 a. m	**0.15**	**0.25**	**0.31**	**0.35**	**0.23**	**0.13**	**— 0.03**	**— 0.10**	**— 0.06**	**0.10**	**0.09**	**— 0.07**	**0.12**
5-6 a. m	0.34	0.39	0.43	0.34	0.30	0.29	0.27	0.21	0.25	0.44	0.42	0.18	0.33
7 a. m	**0.61**	**0.71**	**0.82**	**0.82**	**0.64**	**0.45**	**0.29**	**0.26**	**0.32**	**0.52**	**0.53**	**0.53**	**0.54**
6-7 a. m	0.46	0.46	0.51	0.47	0.41	0.32	0.32	0.36	0.32	0.42	0.44	0.60	0.42
8 a. m	**1.08**	**1.11**	**1.20**	**1.24**	**0.92**	**0.64**	**0.52**	**0.59**	**0.74**	**0.87**	**0.91**	**1.04**	**0.91**
7-8 a. m	0.47	0.40	0.38	0.42	0.28	0.19	0.23	0.33	0.42	0.35	0.38	0.51	0.37
9 a. m	**1.35**	**1.41**	**1.42**	**1.39**	**1.05**	**0.74**	**0.65**	**0.75**	**0.89**	**1.09**	**1.15**	**1.23**	**1.09**
8-9 a. m	0.27	0.30	0.22	0.15	0.13	0.10	0.13	0.16	0.15	0.22	0.24	0.19	0.18
10 a. m	**1.20**	**1.36**	**1.28**	**1.20**	**0.93**	**0.65**	**0.62**	**0.69**	**0.84**	**1.02**	**1.02**	**1.08**	**0.99**
9-10 a. m	— 0.15	— 0.05	— 0.14	— 0.19	— 0.12	— 0.09	— 0.03	— 0.06	— 0.05	— 0.07	— 0.13	— 0.15	— 0.10
11 a. m	**0.79**	**0.94**	**0.95**	**0.85**	**0.60**	**0.39**	**0.43**	**0.51**	**0.60**	**0.60**	**0.62**	**0.69**	**0.66**
10-11 a. m	— 0.41	— 0.42	— 0.33	— 0.35	— 0.33	— 0.26	— 0.19	— 0.18	— 0.24	— 0.42	— 0.40	— 0.39	— 0.33
12 noon	**0.17**	**0.34**	**0.33**	**0.31**	**0.14**	**0.04**	**0.12**	**0.18**	**0.10**	**0.04**	**0.08**	**0.12**	**0.16**
11-12 a. m	— 0.62	— 0.60	— 0.62	— 0.54	— 0.46	— 0.35	— 0.31	— 0.33	— 0.50	— 0.56	— 0.54	— 0.57	— 0.50
1 p. m	**— 0.60**	**— 0.46**	**— 0.47**	**— 0.53**	**— 0.50**	**— 0.47**	**— 0.35**	**— 0.41**	**— 0.54**	**— 0.59**	**— 0.62**	**— 0.64**	**— 0.51**
12-1 p. m	— 0.77	— 0.80	— 0.80	— 0.84	— 0.64	— 0.51	— 0.47	— 0.59	— 0.64	— 0.63	— 0.70	— 0.76	— 0.67
2 p. m	**— 1.22**	**— 1.11**	**— 1.16**	**— 1.23**	**— 1.09**	**— 0.89**	**— 0.74**	**— 0.83**	**— 1.01**	**— 1.12**	**— 1.11**	**— 1.19**	**— 1.06**
1-2 p. m	— 0.62	— 0.65	— 0.69	— 0.70	— 0.59	— 0.42	— 0.39	— 0.42	— 0.47	— 0.53	— 0.49	— 0.55	— 0.55
3 p. m	**— 1.54**	**— 1.54**	**— 1.63**	**— 1.66**	**— 1.45**	**— 1.24**	**— 1.01**	**— 1.11**	**— 1.25**	**— 1.35**	**— 1.30**	**— 1.45**	**— 1.38**
2-3 p. m	— 0.32	— 0.43	— 0.47	— 0.43	— 0.36	— 0.35	— 0.27	— 0.28	— 0.24	— 0.23	— 0.19	— 0.26	— 0.32
4 p. m	**— 1.41**	**— 1.54**	**— 1.70**	**— 1.79**	**— 1.57**	**— 1.32**	**— 1.13**	**— 1.19**	**— 1.20**	**— 1.23**	**— 1.19**	**— 1.32**	**— 1.38**
3-4 p. m	— 0.13	0.00	— 0.07	— 0.13	— 0.12	— 0.08	— 0.12	— 0.08	0.05	0.12	0.11	0.13	0.00
5 p. m	**— 1.04**	**— 1.27**	**— 1.44**	**— 1.59**	**— 1.36**	**— 1.13**	**— 0.96**	**— 1.03**	**— 0.97**	**— 0.91**	**— 0.87**	**— 0.95**	**— 1.13**
4-5 p. m	0.37	0.27	0.26	0.20	0.21	0.19	0.17	0.16	0.23	0.32	0.32	0.37	0.25
6 p. m	**— 0.65**	**— 0.91**	**— 1.05**	**— 1.08**	**— 0.85**	**— 0.70**	**— 0.60**	**— 0.65**	**— 0.57**	**— 0.58**	**— 0.53**	**— 0.55**	**— 0.73**
5-6 p. m	0.39	0.36	0.39	0.51	0.51	0.43	0.36	0.38	0.40	0.33	0.34	0.40	0.40
7 p. m	**— 0.21**	**— 0.50**	**— 0.59**	**— 0.55**	**— 0.35**	**— 0.26**	**— 0.18**	**— 0.21**	**— 0.13**	**— 0.11**	**— 0.05**	**— 0.09**	**— 0.27**
6-7 p. m	0.44	0.41	0.46	0.53	0.50	0.44	0.42	0.44	0.44	0.47	0.48	0.46	0.46
8 p. m	**0.21**	**— 0.03**	**— 0.08**	**— 0.06**	**0.11**	**0.20**	**0.24**	**0.24**	**0.30**	**0.38**	**0.41**	**0.35**	**0.19**
7-8 p. m	0.42	0.47	0.51	0.49	0.46	0.46	0.42	0.45	0.43	0.49	0.46	0.44	0.46

DIFFERENCES BETWEEN THE HOURLY MEANS, ETC.—Continued.

I. METRIC SYSTEM—Continued.

Hour.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
9 p.m.	**0.52**	**0.36**	**0.42**	**0.43**	**0.56**	**0.61**	**0.59**	**0.66**	**0.72**	**0.74**	**0.69**	**0.64**	**0.58**
8-9 p.m.	0.31	0.39	0.50	0.49	0.45	0.41	0.35	0.42	0.42	0.36	0.28	0.29	0.39
10 p.m.	**0.60**	**0.56**	**0.69**	**0.80**	**0.86**	**0.90**	**0.88**	**0.95**	**0.94**	**0.85**	**0.77**	**0.70**	**0.79**
9-10 p.m.	0.08	0.20	0.27	0.37	0.30	0.29	0.29	0.29	0.22	0.11	0.08	0.06	0.21
11 p.m.	**0.56**	**0.59**	**0.76**	**0.83**	**0.88**	**0.97**	**0.89**	**0.91**	**0.84**	**0.77**	**0.68**	**0.61**	**0.77**
10-11 p.m.	— 0.04	0.03	0.07	0.03	0.02	0.07	0.01	— 0.04	— 0.10	— 0.08	— 0.09	0.09	— 0.02
12 midnight	**0.43**	**0.48**	**0.57**	**0.56**	**0.59**	**0.68**	**0.60**	**0.62**	**0.52**	**0.51**	**0.44**	**0.37**	**0.53**
11-12 p.m.	— 0.13	— 0.11	— 0.19	— 0.27	— 0.29	— 0.29	— 0.29	— 0.29	— 0.32	— 0.26	— 0.24	— 0.24	— 0.24
Mean	0.33	0.33	0.35	0.36	0.31	0.28	0.25	0.27	0.30	0.32	0.31	0.32	0.30

II. ENGLISH SYSTEM.

Hour.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
	Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
1 a.m.	**0.006**	**0.007**	**0.010**	**0.012**	**0.010**	**0.011**	**0.008**	**0.010**	**0.007**	**0.002**	**0.003**	**0.006**	**0.008**
0-1 a.m.	— 0.011	— 0.012	— 0.013	— 0.010	— 0.013	— 0.016	— 0.015	— 0.014	— 0.014	— 0.018	— 0.014	— 0.009	— 0.013
2 a.m.	**—0.007**	**—0.005**	**—0.004**	**—0.002**	**—0.002**	**—0.001**	**—0.005**	**—0.005**	**—0.007**	**—0.011**	**—0.012**	**—0.009**	**—0.006**
1-2 a.m.	— 0.013	— 0.012	— 0.013	— 0.014	— 0.013	— 0.012	— 0.013	— 0.014	— 0.014	— 0.013	— 0.015	— 0.015	— 0.014
3 a.m.	**—0.017**	**—0.014**	**—0.011**	**—0.011**	**—0.010**	**—0.009**	**—0.013**	**—0.014**	**—0.016**	**—0.019**	**—0.022**	**—0.020**	**—0.014**
2-3 a.m.	— 0.010	— 0.009	— 0.008	— 0.009	— 0.008	— 0.007	— 0.008	— 0.009	— 0.009	— 0.008	— 0.010	— 0.011	— 0.009
4 a.m.	**—0.016**	**—0.014**	**—0.013**	**—0.010**	**—0.010**	**—0.011**	**—0.015**	**—0.016**	**—0.018**	**—0.020**	**—0.022**	**—0.018**	**—0.015**
3-4 a.m.	0.001	0.000	— 0.002	0.001	0.000	— 0.002	— 0.002	— 0.002	— 0.002	— 0.002	0.000	0.002	— 0.001
5 a.m.	**—0.007**	**—0.006**	**—0.005**	**0.000**	**—0.003**	**—0.006**	**—0.012**	**—0.012**	**—0.012**	**—0.013**	**—0.013**	**—0.010**	**—0.008**
4-5 a.m.	0.008	0.009	0.008	0.010	0.007	0.004	0.003	0.004	0.006	0.007	0.009	0.008	0.007
6 a.m.	**0.006**	**0.010**	**0.012**	**0.014**	**0.009**	**0.005**	**—0.001**	**—0.004**	**—0.002**	**0.004**	**0.004**	**—0.003**	**0.005**
5-6 a.m.	0.013	0.015	0.017	0.013	0.012	0.011	0.011	0.008	0.010	0.017	0.016	0.007	0.013
7 a.m.	**0.024**	**0.028**	**0.032**	**0.032**	**0.025**	**0.018**	**0.011**	**0.010**	**0.013**	**0.020**	**0.021**	**0.021**	**0.021**
6-7 a.m.	0.018	0.018	0.020	0.018	0.016	0.013	0.013	0.014	0.015	0.016	0.014	0.024	0.016
8 a.m.	**0.042**	**0.044**	**0.047**	**0.049**	**0.036**	**0.025**	**0.020**	**0.023**	**0.029**	**0.034**	**0.036**	**0.041**	**0.036**
7-8 a.m.	0.019	0.016	0.015	0.016	0.011	0.007	0.009	0.013	0.016	0.014	0.015	0.020	0.014
9 a.m.	**0.053**	**0.056**	**0.056**	**0.055**	**0.041**	**0.029**	**0.026**	**0.030**	**0.035**	**0.043**	**0.045**	**0.048**	**0.043**
8-9 a.m.	0.011	0.012	0.009	0.006	0.005	0.004	0.005	0.006	0.006	0.009	0.009	0.007	0.007
10 a.m.	**0.047**	**0.054**	**0.050**	**0.047**	**0.037**	**0.026**	**0.024**	**0.027**	**0.033**	**0.040**	**0.040**	**0.042**	**0.039**
9-10 a.m.	— 0.006	— 0.002	— 0.006	— 0.007	— 0.005	— 0.004	— 0.001	— 0.002	— 0.002	— 0.003	— 0.005	— 0.006	— 0.004
11 a.m.	**0.031**	**0.037**	**0.037**	**0.033**	**0.024**	**0.015**	**0.017**	**0.020**	**0.024**	**0.024**	**0.024**	**0.027**	**0.026**
10-11 a.m.	— 0.016	— 0.016	— 0.013	— 0.014	— 0.013	— 0.010	— 0.007	— 0.007	— 0.009	— 0.016	— 0.016	— 0.015	— 0.013
12 noon	**0.007**	**0.013**	**0.013**	**0.012**	**0.006**	**0.002**	**0.005**	**0.007**	**0.004**	**0.002**	**0.003**	**0.005**	**0.006**
11-12 a.m.	— 0.024	— 0.024	— 0.024	— 0.021	— 0.018	— 0.014	— 0.012	— 0.013	— 0.020	— 0.022	— 0.021	— 0.022	— 0.020
1 p.m.	**—0.024**	**—0.018**	**—0.018**	**—0.021**	**—0.020**	**—0.018**	**—0.014**	**—0.016**	**—0.021**	**—0.023**	**—0.024**	**—0.025**	**—0.020**
12-1 p.m.	— 0.030	— 0.032	— 0.032	— 0.033	— 0.025	— 0.020	— 0.018	— 0.023	— 0.025	— 0.025	— 0.028	— 0.030	— 0.026
2 p.m.	**—0.048**	**—0.044**	**—0.046**	**—0.048**	**—0.043**	**—0.035**	**—0.029**	**—0.033**	**—0.040**	**—0.044**	**—0.044**	**—0.047**	**—0.042**
1-2 p.m.	— 0.024	— 0.026	— 0.027	— 0.028	— 0.023	— 0.016	— 0.015	— 0.016	— 0.018	— 0.021	— 0.019	— 0.022	— 0.022
3 p.m.	**—0.061**	**—0.061**	**—0.064**	**—0.065**	**—0.057**	**—0.049**	**—0.040**	**—0.044**	**—0.049**	**—0.053**	**—0.051**	**—0.057**	**—0.054**
2-3 p.m.	— 0.012	— 0.017	— 0.018	— 0.017	— 0.014	— 0.014	— 0.011	— 0.011	— 0.009	— 0.009	— 0.007	— 0.010	— 0.013
4 p.m.	**—0.056**	**—0.061**	**—0.067**	**—0.070**	**—0.062**	**—0.052**	**—0.044**	**—0.047**	**—0.047**	**—0.048**	**—0.047**	**—0.052**	**—0.054**
3-4 p.m.	0.005	0.000	— 0.003	— 0.005	— 0.005	— 0.003	— 0.005	— 0.003	0.002	0.005	0.004	0.005	0.000
5 p.m.	**—0.041**	**—0.050**	**—0.057**	**—0.063**	**—0.054**	**—0.044**	**—0.038**	**—0.040**	**—0.038**	**—0.036**	**—0.034**	**—0.037**	**—0.044**
4-5 p.m.	0.014	0.011	0.010	0.008	0.008	0.007	0.007	0.006	0.009	0.013	0.013	0.014	0.010
6 p.m.	**—0.026**	**—0.036**	**—0.041**	**—0.042**	**—0.033**	**—0.028**	**—0.024**	**—0.026**	**—0.022**	**—0.023**	**—0.021**	**—0.022**	**—0.029**
5-6 p.m.	0.015	0.014	0.015	0.020	0.020	0.017	0.014	0.015	0.016	0.013	0.013	0.016	0.016
7 p.m.	**—0.008**	**—0.020**	**—0.023**	**—0.022**	**—0.014**	**—0.010**	**—0.007**	**—0.008**	**—0.005**	**—0.004**	**—0.002**	**0.004**	**—0.011**
6-7 p.m.	0.017	0.016	0.018	0.021	0.020	0.017	0.016	0.017	0.017	0.018	0.019	0.018	0.018
8 p.m.	**0.008**	**—0.001**	**—0.003**	**—0.002**	**0.004**	**0.008**	**0.009**	**0.009**	**0.012**	**0.015**	**0.016**	**0.014**	**0.007**
7-8 p.m.	0.016	0.018	0.020	0.019	0.018	0.018	0.016	0.018	0.017	0.019	0.018	0.017	0.018
9 p.m.	**0.020**	**0.014**	**0.016**	**0.017**	**0.022**	**0.024**	**0.023**	**0.026**	**0.028**	**0.029**	**0.027**	**0.025**	**0.023**
8-9 p.m.	0.012	0.015	0.020	0.019	0.018	0.016	0.014	0.016	0.016	0.014	0.011	0.011	0.015
10 p.m.	**0.024**	**0.022**	**0.027**	**0.032**	**0.034**	**0.035**	**0.035**	**0.037**	**0.037**	**0.033**	**0.030**	**0.028**	**0.031**
9-10 p.m.	0.003	0.008	[illegible]	0.014	0.012	0.011	0.011	0.011	0.009	0.004	0.003	0.002	0.008
11 p.m.	**0.022**	**0.023**	**0.030**	**0.033**	**0.035**	**0.038**	**0.035**	**0.036**	**0.033**	**0.030**	**0.027**	**0.024**	**0.030**
10-11 p.m.	— 0.002	0.001	0.003	0.001	0.001	0.003	0.000	— 0.002	— 0.004	— 0.003	— 0.004	— 0.004	— 0.001
12 midnight	**0.017**	**0.019**	**0.022**	**0.022**	**0.023**	**0.027**	**0.024**	**0.024**	**0.020**	**0.020**	**0.017**	**0.014**	**0.021**
11-12 p.m.	— 0.005	— 0.004	— 0.007	— 0.011	— 0.011	— 0.011	— 0.011	— 0.011	— 0.013	— 0.010	— 0.009	— 0.009	— 0.009
Mean	0.013	0.013	0.014	0.014	0.012	0.011	0.010	0.011	0.012	0.013	0.012	0.013	0.012

Inferences.—A careful examination of the first part of this table, which contains the differences between the hourly means and the monthly means, serves principally to confirm in a marvelous manner all that we could say regarding the laws of the double daily oscillation of the barometer;

but, in the second place, or from the differences between each one of the hourly means and that immediately preceding, the following conclusions may also be deducted:

(1) In general, the fall of the barometer is more marked from 0 to 2 a. m. and from 11 a. m. to 2 p. m. than in the other hours of descent.

(2) Among the hours of ascent the rise is much more pronounced from 5 to 8 a. m., and from 5 to 9 p. m.

(3) In all the months the differences between 3 and 4 a. m. and 3 and 4 p. m. are very insignificant, which points out the fact that between these two hours the minimums of the dawn and of the afternoon must take place.

(4) The least morning differences are observed—with the exception of the month of April—between 9 and 10 a. m., it being noticed, besides, that even in the other months the difference between these two hours is very small, in comparison to that between 10 and 11 a. m. From this it may be deduced, in confirmation of what was said in the preceding paragraph, that the morning maximum is usually registered in the neighborhood of 9, at times a little before this hour, but more commonly a little after; that is to say, between 9 and 9:30 a. m.

(5) The least night difference is from 10 to 11 p. m., except in November and December, in which months the difference is least from 9 to 10 p. m. This would tend to prove that in these last two months the hour of the nightly maximum advances a little, being generally registered between 10 and 11 p. m.

(6) In general, the differences are less in the hours nearest the maxima and minima, and they increase as they depart from them and again gradually diminish as the following maximum or minimum approaches; and, indeed, examining day by day the curves traced by the Sprung-Fuess barograph since it was installed in this observatory, in 1886, it is noted that in the neighborhood of the maxima and minima the atmospheric pressure remains for a time almost stationary, without rising or falling, the beginning and the end, both of the barometric ascent and descent, being, moreover, generally very slow.

The barometrical gradient.—The barometric gradient in cyclone storms is in proportion to the force of the horizontal rotation by which it is produced. This rotation depends in its turn not only on the radially operating component, which loses its horizontality as it nears the center, but also on the tangentially operating component which, near the center, grows very large, as was pointed out in Chapter I. Eliot says:[1]

> It has been already pointed out that even in the finest weather the barometer at the sea level not only varies in height from day to day and from hour to hour at the same place, but also varies from place to place at the same instant. It is also found, more specially in tropical regions, that the barometer varies fairly regularly in going from place to place at the same instant. Hence it is that at the same hour the barometer is low in certain districts and high in others. An area in which the barometer (reduced to sea level) stands at a lower level than in neighboring districts is called an area of barometric depression or an area of depression. The weather charts published by India and other meteorological departments give special prominence to areas of depression, for stormy weather is invariably found in such areas. These depressions may be of small extent and amount, or they may be large. It is, however, most important to remember that all such depressions, however they may differ in size and intensity, have certain features in common. These have been already stated in connection with air motion, but it is desirable to restate them. In such an area it is found that pressure diminishes with approximate regularity from the outside of such an area to some point within it. This point is conveniently called the center of the depression. It is also found that in such an area the air moves in a rotatory manner in such a way that it is not only moving round the center but also is drawn into it, or in fact that the air motion in such an area always forms a cyclonic circulation. Such areas of low barometer or barometric depression are not permanent. They commence to form and increase for some time in size and intensity, at the same time that they usually appear to advance in some direction, just as a temporary whirl in a stream of water moves for some time along with the stream, and then disappears. After some time the barometer rises in the area, and the depression gradually fills up and disappears. *It should, hence, be carefully borne in mind that an area of barometric depression is necessarily an area of cyclonic circulation, and also that if the depression increases in amount and becomes large, the cyclonic circulation, which is at first feeble,*

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[1] "Handbook of Cyclonic Storms in the Bay of Bengal," Chap. I, p. 24.

becomes more and more vigorous and may gradually develop into a cyclonic storm or hurricane. Cyclonic storm areas are always areas of barometric depression and of cyclonic air circulation. A cyclonic circulation denotes a particular kind of air motion irrespective of whether the air motion is feeble, moderate, or violent. A cyclonic storm, cyclone, hurricane, or typhoon is a rapid or violent cyclonic circulation of large extent.

The preceding remarks show that in an area in which the barometer falls from the outside to a central point, the barometric depression is invariably associated with a particular kind of air motion. This is an illustration of a very important meteorological principle, viz, that *winds are strictly and closely related to changes of pressure.* It is hardly necessary to state that pressure plays exactly the same part with reference to air that slope or level does with respect to water. If the water stands at the same level everywhere there will be no motion. But if there is a difference of level, and the water is free to move, it will at once commence to move from the higher to the lower level. Similarly, if at the level of the sea the barometer stood everywhere at the same height, or pressure were uniform, or unchanged, from place to place, the air would be at rest or in equilibrium. If, however, it diminishes from one district to another, it is always found that the air is in motion from the district of higher pressure towards the district of lower pressure. If the pressure diminishes very slowly, the winds are found to be gentle; but if pressure diminishes quickly, the air moves rapidly. In fact, just as water moves more rapidly down a slope the steeper the descent, the more rapidly does air move as the pressure diminishes more rapidly with distance. Hence it is clear that we need a unit in which to express the rate at which pressure increases or diminishes from one point to another on the earth's surface. The term now generally used by all meteorologists is "baric gradient, or the fall or rise of pressure in hundredths of an inch per quarter degree."

The relation is somewhat complicated, and has been expressed more or less imperfectly in various mathematical formulas. It will be sufficient for the sailor to state it roughly in words.

Remarks.—The theory assumes that the tangentially operating component, and therefore also the barometrical gradient, increases in the same measure as the radially operating component decreases. A close observation of the movement of the barometer in places over which the lower part of a cyclone has passed centrally does not show any such increase in the fall of the barometer; on the contrary, in the zones A, B, C, D, into which we have imagined the cyclone divided, we meet very striking differences. The curve *d* of Plate I entirely bears out this statement. It is the curve of one of the severest typhoons (October 20, 1882) which have passed over the Capital of the Philippines. The barometer began to fall as soon as the cyclone reached Manila. The daily oscillation of the barometer was, however, maintained in the zones A and B, except that the hour of the minimum was somewhat earlier on the afternoon of the 19th. In the zone C the fall was more rapid, but the regular movement was, nevertheless, maintained, especially in the posterior part of the storm. In the innermost part of the region C, in the zone D, and in those parts of the whirl which lay around the center, the fall was very quick; hence we do not find a vestige of the daily movement of atmospheric pressure. We could adduce several analogous examples. Hence the numerical proportion of the gradual fall is by no means the same along the whole length of the radius; and even less uniform is the downward movement of the barometer in those regions which are not diametrically traversed by the vortex of the typhoon, as is shown by the curves *c, b,* and *a.*

The value of barometrical readings.—From what has been said it follows that, although the fall of the barometer gives evidence as to the size, form, and intensity of the typhoon, as well as the distance at which the center passes, these data are only relative and are, moreover, strongly influenced by general causes, exterior to the cyclone, such as for instance the daily oscillation of the atmospheric pressure.

We have, however, to except the case in which the vortex passes close to the locality of the observer, and also the relation between the barometer and the progressive movement of the cyclone.

When a locality comes under the influence of the first spirals of the body of a cyclone the barometer, in the Tropics, and even in high latitudes, falls at the time of the afternoon minima to a determined height, which depends on the geographical and even the topographical position of the locality and the time of the year. In treating, in the second part, of the precursory signs of a cyclone shown by the barometer, we give a list of the normal heights corresponding to the principal cities of the Far East, together with their monthly variations.

The height of the barometer within the boundary zone of the whirl.—Fr. Faura has ascertained that 755 millimeters (29.725 inches) is the mean height of a barometer for the boundary zone of a typhoon in the Philippines. But as the Archipelago has a very considerable extension from north to south—the outermost latitudes differing by more than 13°—it follows that the normal height and the daily amplitude of Aparri, and of Jolo or Zamboanga must necessarily differ, especially in the months of November, December, January, and February. On the other hand, the yearly variation of the barometer is considerable in Luzon, especially in the north, but it is hardly noticeable in the more southern region of the Archipelago. A difference in the barometric altitude for the limits of the typhoon area must therefore be noticeable, for instance between Aparri and Manila.

The variability depending on the latitude and the yearly range of the barometer are, however, not so great in the Archipelago as in other regions. The reason for this phenomenon must apparently be looked for in the geographical situation. Although the outermost isobars of the great center of low pressure, which in springtime extends to the south of China, reach our region, and likewise the region of high pressure which governs the Continent during winter, shows its effect in some degree, yet neither the one nor the other exerts influence of any great moment.

How to ascertain the height indicating the boundary.—We divide the Archipelago into three sections: The southern one is bounded by the parallels of 4° north and 10° 24′ north (Iloilo), the middle one by the parallel of Iloilo and that of Bolinao, 16° 30′ north, the northern by the parallel of Bolinao and that of 22° north.

The height of the barometer and the daily and yearly normal variations can be represented for the first division by Zamboanga (6° 54′ north), for the second by Manila (14° 35′ north), and for the third by Aparri (18° 22′ north).

The mean atmospheric pressure for the three groups into which we have divided the year for these three stations is as follows:

Place of observation.	Latitude (north).		First group.		Second group.		Third group.	
	°	′	*Mm.*	*Ins.*	*Mm.*	*Ins.*	*Mm.*	*Ins.*
Zamboanga	6	54	758.0	29.84	757.3	29.82	757.6	29.83
Manila	14	35	760.7	29.95	758.7	29.87	757.1	29.81
Aparri	18	22	761.8	29.99	758.9	29.88	757.1	29.81
Hongkong	22	18	764.8	30.11	760.8	29.95	755.6	29.75

We call attention to the great difference in the mean atmospheric pressures at Hongkong and Aparri.

We have compiled a table which is intended to draw attention at each place within the typhoon region of the Northern Hemisphere in the Far East to any depression which may possibly approach. The values show the smallest probable height of atmospheric pressure in the most extreme part of zone A. Should, therefore, the barometer fall in any place to the level which is given for the various groups and regions, we must carefully note whether the instrument shows an inclination to fall still further. Should this be the case, we are justified in inferring that the place lies in the outermost zone of a typhoon.

BAROMETER READINGS IN THE OUTER LIMIT OF ZONE A OF A TYPHOON IN THE NORTHERN HEMISPHERE.

Between parallels—	Milli-meters.	Inches.	Remarks.
(*a*) 0°-11° N.	756	29.76	All through the year.
(*b*) 11°-17° N.	756	29.76	During the months of the first group.
	755	29.73	During the months of the second and third groups.
(*c*) 17°-21° N.	757	29.80	During the months of the first group.
	756	29.76	During the months of the second group.
	755	29.73	During the months of the third group.
(*d*) 21°-25° N.	760	29.92	During the months of the first group.
	757	29.80	During the months of the second group.
	753	29.65	During the months of the third group.
(*e*) 25°-32° N.	765	30.12	During the months of the first group.
	762	30.00	During the months of October and November.
	758	29.84	During the months of April and May.
	753	29.65	During the months of the third group.
(*f*) 32°-35° N.	763	30.04	During the months of the first group.
	758	29.84	During the months of the second group.
	754	29.69	During the months of the third group.
(*g*) 35°-40° N.	761	29.96	During the months of the first group.
	757	29.80	During the months of the second group.
	754	29.69	During the months of the third group.
(*h*) 40°-50° N.	756	29.76	All through the year.

As the relative position of seas and continents has a decided influence upon the normal pressure, the values given in this table hold good with the following restrictions:

(*a*) From Sumatra to the Caroline Islands; or from the ninety-fifth to the one hundred and fiftieth meridian east of Greenwich.

(*b*) From the Gulf of Siam to Ladrones Islands; or from the one hundredth to the one hundred and forty-fifth meridian east of Greenwich.

(*c*) From Tonkin to Ladrones Islands; or from the one hundred and fifth to the one hundred and forty-fifth meridian east of Greenwich.

(*d*), (*e*), (*f*), (*g*), (*h*) From the Asiatic Continent to the one hundred and fiftieth meridian east of Greenwich.

Slow, distinct, and rapid fall of the barometer.—If we examine the curves traced by the registering apparatus during the passage of a cyclone we will find three very characteristic phases. In the first place, a slow but continuous descent is observed, during which the normal daily oscillation, which gradually diminishes, is not wholly lost, but merely changed. The fall of the barometer during this period is called the slow fall. A more marked descent then follows, during which the normal oscillation becomes nearly effaced; this we call the distinct fall. There is also in some cyclones a very abrupt and violent fall of the pressure, and this we call the rapid fall. The curve *a* of Plate I shows the slow fall; *b*, the distinct fall; while *c* and *d* give the type of the curves traced by the barograph when the vortex passes near to, or over, the place. The three falls are perfectly distinguished in them. They show the slow fall from *m* to *n*; the distinct fall from *n* to *p*, and the rapid from *p* to *o*. We prescind here from all other purely accidental barometric movements caused by wind squalls in the outermost part of the cyclone and by the rain squalls in the inner zones.

In the following table we give the heights of the barometer according to the barograph curves of Manila. They have been noted for the beginning of the slow and distinct fall during the passage of some of the more notable typhoons. We confine ourselves to the groups 2 and 3, which are the most dangerous for the Visayas and Luzon:

HEIGHTS OF THE BAROMETER ACCORDING TO THE BAROGRAPH CURVES.

Group.	Year.	Month and day.	Height of barometer— At the beginning of the slow fall. Millimeters.	Inches.	At the beginning of the distinct fall. Millimeters.	Inches.
2	1881	May 23	757.35	29.817	755.60	29.749
2	1893	May 13	56.00	.764	53.00	.646
2	1881	Oct. 18	56.50	.784	55.40	.741
2	1882	Oct. 19	56.90	.800	55.20	.733
2	1883	Oct. 28	56.80	.796	55.30	.737
2	1894	Oct. 2	57.70	.831	55.50	.745
2	1882	Nov. 3	57.00	.804	56.00	.764
2	1884	Nov. 17	59.77	.913	57.50	.823
2	1885	Nov. 6	59.56	.904	57.00	.804
2	1890	Nov. 9	56.80	.796	55.80	.756
2	1891	Nov. 15	56.90	.800	55.00	.725
2	1892	Nov. 20	57.00	.804	53.00	.646
Mean			**757.36**	**29.817**	**755.36**	**29.739**
3	1881	June 28	56.50	.784	55.45	.743
3	1896	June 5	57.20	.812	55.50	.745
3	1883	July 10	55.75	.755	55.40	.741
3	1884	July 9	56.00	.764	54.00	.686
3	1884	July 28	57.41	.819	55.20	.733
3	1888	July 12	57.20	.812	55.47	.744
3	1881	Aug. 19	57.26	.814	55.40	.741
3	1884	do	57.25	.814	55.45	.743
3	1883	Sept. 29	57.91	.839	55.50	.745
3	1887	Sept. 18	57.49	.822	55.50	.745
3	1887	Sept. 23	58.74	.873	55.00	.725
3	1890	Sept. 28	55.60	.749	55.00	.725
3	1893	Sept. 30	54.60	.709	54.00	.686
3	1894	Sept. 14	55.50	.745	52.10	.611
3	1894	Sept. 16	54.30	.697	53.50	.661
Mean			**756.58**	**29.787**	**754.83**	**29.718**

Inferences.—(1) The height of the barometer for the months belonging to the second group is on an average somewhat greater than that for the third. This difference is due to the fact that the extreme and neighboring months of the different groups have characteristic qualities in common. Since, for instance, the height of the barometer which corresponds to the outermost part of a storm center for Manila and the middle part of the Archipelago amounts on an average to 756 millimeters (29.76 inches) in December it is but natural that, should November prevail in the table for the months of the second group, a somewhat higher value will appear than otherwise might be expected for this group.

(2) If we deduct from the mean height 757.36 millimeters (29.817 inches), which has been found for the slow fall or for the entry of the place into the typhoon, for the months of the second group, a quantity somewhat less than that corresponding to the barometric oscillation in these months, that is, 2 millimeters (0.078 inch), then 755.36 millimeters (29.739 inches) remains as the limit of height indicating the boundary.

But if we subtract the probable amplitude for the months of the third group, 1.95 millimeters (0.077 inch), from the mean height of the maximum, 756.58 millimeters (29.787 inches), at which reading the place commences to enter the first spirals of the typhoon, 754.63 millimeters (29.710 inches) will remain as the limit of height.

The average for both the values found, 755.36 millimeters (29.739 inches) and 754.73 millimeters (29.710 inches), gives the height, 755 millimeters (29.72 inches); that is to say, the height which is valid for Manila and the center of the Archipelago, as being the extreme value for the entry into the outermost spirals of a typhoon, during the months of the second and third groups.

(3) If we deduct the probable mean value of the variation, 1.85 millimeters (0.073 inch), from the average value for the months of the second and third groups, 755.36 millimeters (29.739 inches) and 754.83 millimeters (29.718 inches), respectively, we shall find as smallest values 753.51

millimeters (29.666 inches) and 752.98 millimeters (29.645 inches), or on an average 753.25 millimeters (29.656 inches), thus showing that the distinct fall usually begins at the inner limits of zone A, and at the outer ones of zone B, or when the typhoon is entering the locality.

The height of barometer and the distance from the center.—This relation can have but little permanence, because the extension and the conditions of cyclones are of such a varied and uncertain nature; but if we confine ourselves to average values and suitable limits, it will not be difficult to find relations which may serve the observer as a guide. According to experience gained in Manila we may take for the zone A 120 to 500 nautical miles as the average distance of the center, and for the minimum during the afternoon in Manila and the Central Philippines the limits of 755, 756, and 751 millimeters (29.72 or 29.76 inches and 29.57 inches). This great variety in the extreme limits is not unnatural, for, while some of the cyclones have only a small dimension, others again expand over a very large area, so that in both cases the same phenomena may appear in the most extreme zones. The uncertainty of the distance within the limits of a cyclone can not lead the observer to an error involving grave consequences, because in the other zones the limits are much smaller and therefore the movement of the barometer shows with far greater certainty whether one of them has been reached. The probability of estimating the distance correctly increases with the further fall of the barometer.

In the following tables we illustrate by examples the relations of the height of the barometer to the distance and bearing of the center for the various zones:

ZONE A—BETWEEN 120 AND 500 NAUTICAL MILES FROM THE CENTER.

[Height of barometer, from 756 to 751 millimeters (29.76 to 29.57 inches).]

Group.	Year.	Month.	Barometric minimum.		Smallest distance of the center.[1]	Bearing of the center.
			Millimeters.	Inches.		
1	1893	December	755.80	29.756	260	S.
1	1890	January	55.65	.751	310	S.
1	1893	do	56.52	.785	170	S.
2	1890	April	54.57	.708	140	S.
2	1894	May	53.41	.662	130	S.
2	1889	October	53.00	.646	120	S.
2	1893	November	55.75	.755	130	S.
3	1887	June	53.40	.662	130	S.
3	1881	July	54.16	.692	200	S.
3	1892	August	55.50	.745	290	S.
3	1891	September	54.00	.686	120	S.
Mean			**754.71**	**29.718**	**182**	
2	1893	October	753.50	29.666	350	N.
3	1883	July	50.64	.554	120	N.
3	1889	do	55.84	.758	310	N.
3	1891	do	53.00	.646	260	N.
3	1885	August	52.50	.627	270	N.
3	1881	September	52.91	.642	350	N.
3	1887	do	54.64	.711	220	N.
3	1890	do	52.50	.627	270	N.
3	1892	do	55.00	.725	360	N.
3	1894	do	54.55	.707	280	N.
Mean			**753.51**	**29.666**	**279**	
3	1888	June	753.91	29.682	270	W.
3	1888	do	54.06	.688	160	W.
2	1894	May	53.41	.662	300	E.
2	1894	do	53.82	.679	290	E.
2	1893	October	54.75	.715	250	E.
3	1890	July	53.80	.678	340	E.
3	1891	August	53.10	.650	340	E.
3	1881	September	54.82	.718	350	E.
3	1894		54.80	.717	440	E.
Mean			**754.05**	**29.687**	**304**	

[1] Distance of the center from Manila, in nautical miles.

The table confirms what we have said concerning the readings of the barometer. Should the center pass to the north, the barometer reaches for equal distances a lower level than if it pass to the south.

ZONE B—BETWEEN 60 AND 120 NAUTICAL MILES FROM THE CENTER.

[Height of barometer, 751 to 747 millimeters (29.57 to 29.41 inches).]

Group.	Year.	Month.	Barometric minimum.		Distance of the center.[1]	Bearing of the center.
			Millimeters.	Inches.		
1	1881	December	750.89	29.563	80	S.
2	1894	May	54.63	.710	100	S.
2	1883	November	52.88	.641	70	S.
2	1889	do	50.27	.538	90	S.
2	1891	do	50.81	.560	70	S.
3	1892	June	54.89	.720	80	S.
3	1891	July	50.98	.567	70	S.
Mean			**750.96**	**29.614**	**80**	
2	1881	October	749.35	29.503	120	N.
2	1894	do	48.50	.469	80	N.
2	1879	November	52.10	.611	90	N.
3	1883	July	51.00	.567	120	N.
3	1884	do	49.79	.519	80	N.
3	1880	August	53.10	.646	110	N.
3	1884	do	50.22	.537	90	N.
3	1884	September	50.76	.558	80	N.
3	1884	do	48.01	.449	70	N.
Mean			**750.31**	**29.540**	**98**	

[1] Distance of the center from Manila, in nautical miles.

The typhoons which pass to the south of Manila ought to show here a greater reading of the barometer.

ZONE C—BETWEEN 10 AND 60 NAUTICAL MILES FROM THE CENTER.

[Height of barometer, 747 to 740 millimeters (29.41 to 29.13 inches).]

Group.	Year.	Month.	Barometric minimum.		Least distance of the center.[1]	Bearing of the center.
			Millimeters.	Inches.		
2	1885	November	748.93	29.486	50	N.
2	1893	May	46.17	.378	13	N.
3	1890	September	47.66	.436	30	N.
3	1894	do	42.34	.227	60	N.
3	1894	do	45.94	.379	30	N.
Mean			**746.21**	**29.378**	**36**	

[1] Distance of the center from Manila, in nautical miles.

The probable distance of the center fluctuates, therefore, very much in zone A, as much as from 120 to 500 miles, and the probable height of the barometer varies for Manila and the central part of the Archipelago between 755 or 756 and 751 millimeters (29.72 or 29.76 and 29.57 inches).

In the second zone the distance lies between 60 and 120 miles and the height of the barometer between 751 and 747 millimeters (29.57 and 29.41 inches). In zone C the limits for the distances are still narrower, from 10 to 60 miles, but they are broader for the height of the barometer, viz, from 747 to 740 millimeters (29.41 to 29.13 inches).

Zone D, which comprises the regions of the absolute and relative calms and neighborhood of the vortex, deserves a special investigation, wherefore we shall treat it somewhat more at length. In the following table we have united all the more important data collected at the points of the Archipelago over, or very close to, which, a cyclonic vortex has passed. Special attention is drawn to some remarkable peculiarities:

ZONE D—0 TO 10 NAUTICAL MILES FROM THE CENTER.

[Height of barometer less than 741 millimeters (29.17 inches).]

Cyclone number.	Station.	Month and day.	Year.	Barometric minimum.		Rapid fall. Average amount per hour.		Rapid fall. Duration. hours.	Wind. Direction.	Wind. Force.	Velocity of the progressive movement.[1]	Barometric gradient.[2]	Remarks.
				Mm.	*Ins.*	*Mm.*	*Ins.*						
I	Manila	Oct. 20	1882	727.75	28.652	5.1	0.201	4.5	WNW	12[2]	15.8	18.9	Destructive effects.
II	do	Nov. 4-6	1882	35.79	.968	2.6	.102	4	NW. by W.	12[2]	9.6	16.0	Destructive effects; wind 56 meters per second; 125.3 miles per hour.
III	Aparri	Sept. 25-27	1888	27.42	.639	2.6	.102	6	Third and fourth quadrant.	10	11.2	13.6	No destructive effects; no calm; no clearing up worth mentioning.
IV	San Isidro	Sept. 28-30	1890	43.53	29.273	0.8	.032	9	Second and third quadrant.	10	8.7	5.3	Force of the wind did not decrease; the sky did not clear up.
V	Manila	Nov. 10-13	1890	43.84	.286	0.9	.035	5	SW	12	7.1	7.7	36 meters per second; 80.5 miles per hour.
VI	Tabaco	Nov. 10-12	1890	42.07	.216	1.2	.047	5	NNW	11	7.1	10.1	The sky cleared up partially; the rain-squalls stopped.
VII	Albay	Nov. 14-16	1891	27.80	28.654	3.9	.154	3	NNW	12[2]	10.8	21.3	Destructive effects.
VIII	Bayombong	Oct. 28-30	1892	48.04	29.254	1.4	.055	5	SSW	10	8.3	9.4	No calm and no clearing up.
IX	Albay	May 13-14	1893	37.00	.016	2.0	.079	5	NNE	10	10.0?	11.8	The center passed at a considerable distance.
X	Vigan	Sept. 26-27	1893	44.47	.311	0.6	.024	6	S	12	9.6	3.6	It cleared somewhat up in the southwest; in the calm a baffling southeast wind.
XI	Tuguegarao[3]	Sept. 29-30	1893	10.45	27.971	5.4	.213	6	NW.	12[2]	10.8	29.5	Destructive effects; no calm and no clearing up.
XII.	San Fernando (Union).	Sept. 16-18	1894	37.15	29.022	0.7	.028	5	ESE	12[2]	7.1	17.7	Typhoon squalls; partial centers in the north.
XIII	Cape Bolinao	do	1894	40.89	.170	0.3	.012	5	N	9	7.1?	2.4.	Partial centers in the south.
XIV	San Isidro	do	1894	36.80	.008	1.5	.059	6	W., SSW.	8	7.1	11.2	Center before the division.

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[1] Miles per hour.

[2] In hundredths of an inch per one-fourth of an equatorial degree.

[3] The center passed very near to the south of Tuguegarao, and the barometer fell in the central calm to 704 millimeters (27.72 inches) This was the lowest point which had been observed during the time of the existence of the Observatory until the typhoon of October, 1897 broke the record. (See No. XXII.)

ZONE D—0 TO 10 NAUTICAL MILES FROM THE CENTER—Continued.

[Height of barometer less than 741 millimeters (29.17 inches).]

Cyclone number.	Station.	Month and day.	Year.	Barometric minimum.		Rapid fall.			Wind.		Velocity of the progressive movement.[1]	Barometric gradient.[2]	Remarks.
						Average amount per hour.		Duration, hours.	Direction.	Force.			
				Mm.	*Ins.*	*Mm.*	*Ins.*						
XV	Bayombong	Oct. 2-4	1894	741.25	29.184	1.5	0.059	7	NE	9	7.9	10.7	Winds of the rear baffing.
XVI	San Fernando (Union).	do	1894	38.35	.069	2.4	.094	3	N	12[2]	7.9	17.7	
XVII	Aparri	Nov. 16-18	1894	30.26	28.751	2.7	.106	6	ESE	12[2]	7.5	21.8	Partial clearing up; relative calm.
XVIII	do	Nov. 1-2	1895	40.79	29.166	2.8	.110	4	E	10			
XIX	Agaña	Nov. 20-21	1895	29.96	28.741	8.1	.319	2.5	NE., SE	11			
XX	Aparri	July 27-29	1896	716.30	.201	5.8	.228	5	Third and fourth quadrant.	11	13.0	26.0	No destructive effects; central calm.
XXI	do	Oct. 18-20	1896	740.00	29.134	3.5	.138	4.5	NE	12[3]			Destructive effects; secondary typhoon a kind of tornado.
XXII	Tanauan (Leyte).[3]	Oct. 12-13	1897	693.98	27.323								

[1] Miles per hour.

[2] In hundredths of an inch per one-fourth of an equatorial degree.

[3] Discussed in "El Baguio de Sámar y Leyte." Fr. Algué. Manila, 1898.

In column 7 we give the whole duration of the rapid fall, and in column 6 the mean fall per hour. In the typhoon of Manila on October 20, 1882, for instance, the duration of the rapid fall was four and one-half hours, the mean velocity per hour 5.1 millimeters (0.201 inch). The barometer fell, therefore, 22.95 millimeters (0.904 inch) in four and one-half hours.

We derived the barometrical gradient (column 11) from the velocity of the translatory movement in column 10, and from that of the rapid fall.

Practical conclusions.—(1) A cyclone which shows a destructive nature must not only have a force of 12 (Beaufort scale) but the wind must also have a greater velocity than 36 meters per second (80.5 miles per hour).

(2) There seems to be good reason for believing that the gradient does not always remain strictly proportional to the force of the wind; and even in the closest neighborhood of the center this is not always the case. In order to be convinced of this we must compare the data which have reference to the cyclones III, IV, V, VI, IX, X, XVIII, XIX, XX. The causes for this phenomenon are not known. We ascribe them to the nutation of the axis of the cyclones, which may possibly exercise such an effect without altering the barometrical gradient. Compare also the cyclones XII-XIV, XV, XVI, and XVIII.

(3) The fall of the barometer alone, even if it should be extraordinary, is not sufficient to characterize a cyclone as intense and destructive. In the typhoon XX the barometer fell to 716 millimeters (28.19 inches), yet this showed no destructive character. In opposition hereto stands the typhoon XXI, which, with 740 millimeters (29.13 inches) as lowest height of the barometer, brought destruction with it. In the typhoon IX, in spite of the barometer having fallen to 737 millimeters (29.02 inches), the wind had only the force of 10, while in the cyclone V, with more than 743 millimeters (29.25 inches), the force of the wind was already 12.

(4) Should the barometer fall to 740 millimeters (29.13 inches), it may be asserted with sufficient probability that the center has passed or will pass through the place, because column 5 of the preceding table gives 735 millimeters (28.94 inches) as the mean value of the barometric reading for zone D.

(5) The barometric gradient is not symmetrically distributed even near the center; that is, we do not find equal gradients for equal distances from the center. Compare the barometrical curves, especially those of the cyclone I.

But even though the barometric gradient does not strictly indicate the exact force of the wind, we may very often take it as such and derive the gradient with an accuracy sufficient for all practical purposes from the force of the wind, and from that the distance of the center. We conclude this chapter with a practical application, by way of example.

During the most important typhoon of 1894, which crossed the meridian of Manila in the morning of September 17, the following observations were made:[1]

The difference of the barometer between San Isidro and Manila was 4.7 millimeters (0.185 inch) at 3 a. m. on September 17. The two places lie 48 nautical miles from each other. The barometric gradient was therefore 5.8. The distance between San Isidro and Bayombong is 66.9 nautical miles. If along the line of the meridian the fall was equal, which we believe to have been the case, and if along this line there were no perturbating causes, as is supposed, the center had to pass about 10 nautical miles to the north of San Isidro, or 58 nautical miles from Manila; that is to say, exactly half way between Bayombong and Manila and very close to Cabanatuan, a place which lies about 11 nautical miles to the north of San Isidro.

Based upon the conclusions so far obtained a new instrument has been devised by the author, which is called the barocyclonometer. It will be fully described in Chapter VI of Part II.

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[1] Taken from the work "Baguios ó Tifones de 1894," pp. 70–72.

CHAPTER V. RAIN AND CLOUD AREAS IN CYCLONES.

Before entering upon the question of cyclonic rains it may be useful to premit some remarks concerning the different kinds of rain and their relations to the pressure of the atmosphere.

(I) **The rain, its different types and their relation to the barometric movements.**—For the sake of clearness we distinguish four different types of rain.

(1) "Purely local rains." For reasons stated below we term these rains purely local, though they sometimes are of great extent. Their formation is almost entirely due to the rapid ascent of small masses of overheated air saturated with water vapors, which are carried by the wind to regions in which conditions favor condensation and precipitation of the vapors. These rains occur generally between 9 a. m. and 6 p. m. Their coming is heralded by a clear and bright sky during the night and a high dew point. Usually they put in their appearance when the barometer shows normal pressure, but sometimes also during high, occasionally even during very high pressure. Whenever in a particular region there is a propensity toward the above-mentioned conditions the occurrence of these rains can be predicted. To this class belong the copious rains on the eastern coasts of our Archipelago, which we are accustomed to forecast not only from day to day but several days in advance, and this precisely the more accurately the higher the barometers are.

The essential feature of these rains is that they do not spread through a progressive motion, properly so called; they simply advance as the conditions which cause them move on—invariably it rains simultaneously at all places at which the same conditions prevail, a statement which is fully borne out by the rains which during the months of December, January, and February occur at Manila, on the entire western coast of Luzon, in the interior of the Visayas, etc. These rains are, however, rare compared with those of the same class which abound on the eastern coasts.

(2) "Thundershowers" are rains which are likewise local but which exhibit an onward motion, even if for only a comparatively short distance; they are always accompanied by electrical phenomena, mostly coming on in the afternoon and evening between 1 and 10 p. m., but sometimes in the hot season during the night and the early morning also; they are usually formed in hilly countries and mountain forests, and generally in regions in which, as the sun sinks, the evaporation is greater than in low-lying districts. Should the direction of the clouds and the wind be contrary, the formation of thunderstorms will be favored by it.

Thunderstorms have in every district characteristic peculiarities; they can be predicted only by observers who have closely studied them. They mostly appear during a normal atmospheric pressure, but sometimes also when the barometer is high, very seldom, however, when it stands low. We notice two different barometrical movements when a thunderstorm occurs—either the barometer rises 1 to 3 millimeters (0.04 to 0.12 inch) or more, as has been observed repeatedly in Manila, or it falls quickly, but the whole not to so great an amount.

In confirmation of this important point we exhibit in fig. 5 some facsimiles of the Sprung-Fuess barograph registered during the passage of some thunderstorms over Manila. At the side of the said curves we have traced the mean movement of the barometer corresponding to the respective months, concerning which we note that the (dotted) curves (*a*) and (*c*) are *mean relative curves,* while (*b*), (*d*), and (*e*) are *absolute mean curves.* It must be borne in mind that after the storm had broken the barometer remained relatively higher than corresponds to normal weather, as is evidenced by the curves (*a*), (*b*), (*d*), and (*e*). The storms represented by the curves (*a*) and (*c*) occurred with barometers slightly low; the curve (*b*) was traced on a day of normal pressure, while (*d*) and (*e*) resulted on days of high pressure; which fully confirms what we have said.

If the thunderstorm is already developed when reaching the place of observation, the barometer will rise on its arrival, but it falls if the development takes place principally at the place itself. The height of the barometer will also change, if the thunderstorm begins *near* the place of observation. In the Tropics a connection beween the thunderstorms and the active atmospheric forces appears to exist, which deserves to be mentioned here. A thunderstorm is very probable on days on which the temperature is high and the relative and absolute humidity are also high, but the daily temperature variation is small.

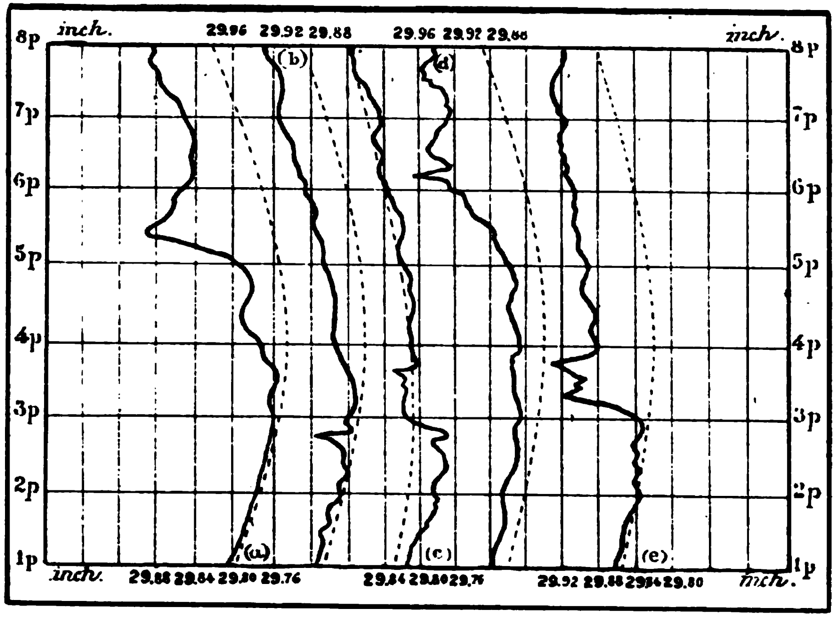
According to the nature of the thunderstorm itself the rains connected therewith can only be predicted a few hours beforehand.

(3) The third kind of rain presents itself as a "light rain," or "drizzle." It usually appears between 1 and 8 a. m. and seldom lasts all day; it is apparently generated by the nightly radiation in strata of air which are somewhat distant from the surface. The wind belonging to a slight depression freshens up at midnight, the sky being clear and bright, and brings with it masses of air saturated with vapor. These conditions produce no rain, but they bring the temperature of the surrounding air, which contains moisture, to the point of precipitation, owing to the nocturnal radiation to a clear sky. The sun generally stops the rain, though sometimes it may rain the whole day if the sun is not strong enough. The indications for this third kind of rain are usually a slight tendency toward the formation of fogs, the formation and redisappearance of small clouds, a greater fall of temperature than usual, and halos around the moon. The nature of all these signs does not permit the occurrence of this type of rain to be predicted from day to day except in a vague and general way—that is, designating indefinite regions. The most that can be done, at least generally, is to foresee them a few hours. We do, however, not wish to deny that in special

CURVES OF THE SPRUNG-FUESS BAROGRAPH

AT MANILA

(Fig. 5.)



(a) *Thunderstorm of May 21.1892* (b) *Thunderstorm of June 2,1899*

(c) *Thunderstorm of October 11.1898* (d) *Thunderstorm of June 14,1899*

(e) *Thunderstorm of August 28,1897*

cases a thorough meteorologist, who is well acquainted with the effects certain winds produce over extended regions, may be able to forecast these rains with certainty. This type of rain as actually observed in the Tropics is of short duration and very light. Abscinding from accidental barometric movements *during precipitation,* these rains occur only during atmospheric pressures which are at least normal, most ordinarily during high pressures.

(4) The fourth type of rain is formed by the squalls and abundant rains during cyclonic disturbances. Of these we shall treat at length anon. They can be predicted in the same way and with the same degree of accuracy as the atmospheric perturbances themselves, and are the only class of precipitations which take place during an essentially low barometer. The accidental barometric changes during their fall are analogous to those that occur during thunderstorms.

(II) **Cyclonic rain.**—The rain which generally accompanies cyclones or cyclonic rain belongs to the fourth class of rains as set forth in the preceding paragraph. We will consider especially (1) its causes; (2) quantity and distribution around the center of the cyclone; and (3) the form and extension of the rain and cloud area, giving special attention to the question of central calms.

Should the air which is more or less saturated with vapor, and near the center of a cyclone, have a centripetal and rapidly ascending motion, move toward the central part of the cyclone, there must at a certain height be usually in existence a stratum, in which the vapors, arriving under various thermal and hygrometric conditions, condense into clouds, which then produce the rain. We say "usually" because the essential conditions for the origin of a cyclone do not absolutely depend on the condensation of aqueous vapor, and still less on rain. There may, in fact, exist a considerable cyclonic movement and an atmospheric depression, with little or no rain at all, at least for a few hours. On the other hand, in an atmosphere containing no vapor, if the dry air be in a condition of unstable equilibrium, every slight increase of temperature in a stratum will generate a vertical cyclonic movement, and this will produce a depression of the barometer toward the center. Likewise, as often as the temperature of any area rises notably above that of the surrounding air, a more or less energetic cyclonic movement will be developed. This, however, does not suffice for the formation of clouds which are thick and dense enough to produce rain. Should the energy be great, it may happen occasionally that the vapor in a cyclone condenses into an immense mass of clouds, but is not precipitated as rain.

The level at which vapor condenses depends on the degree of saturation of the inflowing air at the surface of the earth, and therefore on the difference between the air temperature, and the dew-point at the beginning of the rapid rising motion.

It does not lie within the scope of this work to treat of the complicated theoretical formulæ which define the decrease in temperature of ascending air saturated with moisture, which is due to its upward movement. It suffices for our purposes to exhibit in the following table the results of these formulæ for every 100 meters of altitude. Columns 1 and 3 need no explanation, the values in the latter being evidently the heights at which the pressure on the corresponding line of column 1 will be found, if 760 millimeters is assumed to be the barometric reading at sea level. The heading of the middle column gives various temperatures of the ascending air, underneath each of which will be seen the corresponding decrease in temperature (expressed in fractions of 1 degree centigrade) for every 100 meters as the air rises from a given barometric level to the one given in the next line below:

Atmospheric pressure.	Temperature, degrees centigrade.								Altitude.
	—5.	0.	5.	10.	15.	20.	25.	30.	
Mm.									*M.*
760	0.68	0.64	0.58	0.53	0.48	0.43	0.40	0.37	0
700	.66	.63	.57	.51	.46	.42	.38	.36	660
600	.63	.60	.54	.48	.43	.40	.36	------	1,897
500	.60	.56	.50	.45	.40	.37	------	------	3,357
400	.55	.51	.46	.41	.37	------	------	------	5,142
300	.49	.46	.42	------	------	------	------	------	7,550
200	.41	.39	------	------	------	------	------	------	10,680

The altitude at which the vapor commences to condense, or the clouds begin to form, may be determined from the temperature of the air and the dew point. It amounts on an average to 125 meters for every difference of 1° C. between the temperature of the air and that of the dew point. In the following table *t—r* denotes this difference:

Temperature of the air.	35°.	30°.	25°.	20°.	15°.	10°.	5°.	0°.
(*t—r*).	*M.*	*M.*	*M.*	*M.*	*M.*	*M.*	*M.*	*M.*
1°	128	127	127	126	126	125	125	125
2°	255	254	253	252	251	250	250	250
3°	382	380	379	377	376	375	375	375
4°	509	506	505	502	501	500	500	500
5°	635	632	630	627	625	624	624	624
6°	761	758	755	751	748	747	746	745
7°	886	883	879	874	871	868	868	867
8°	1,912	1,009	1,003	997	993	991	990	988

The vapor which becomes condensed first is carried along by the rising air current in the form of a cloud, or of minute droplets, which will be all the more numerous in proportion as the velocity of the current is greater. These particles of water will be hurried along the quicker the smaller they are; drops of different sizes will thus be moving with different velocities, coming in contact with each other, and uniting themselves finally to large drops, which fall to the ground as rain. The drops will be all the larger the stronger the air current is; so that there could be no rain without an ascending air current; at the most we should observe fog or mist which would show itself near the horizon as stratus.[1]

Quantity and distribution of rain around the center of a cyclone.—The amount of rain is therefore dependent on the degree of saturation of the air with moisture, and on the velocity of the currents. These two factors, which are greatly influenced by local conditions, are not only very variable in different cyclones but in the same cyclone also; hence we find a great variety as to the amount and the distribution of rain.

Influence of local conditions on the amount of rain.—The local conditions which have influence on the amount of rain are principally the geographical and topographical positions, as for example, altitude; because the saturation of the air will be affected as it blows across oceans or over continents, or else over mountainous or woodland districts. Besides these local conditions, the velocity of the cyclonic winds has, as is well known, a very great influence. Several localities in the Philippines furnish us with excellent examples of these influences. We will call attention to but a few.

There is a fact which must have called the attention of any diligent observer who has lived for any length of time in Manila, that the typhoons which pass by the south of the capital have a much less violent character than those which cross by the north. This is the case not only when the distances are equal, but even when the center passing by the south is much nearer to the city. The reason why they are felt less is that the typhoons from the south are accompanied by less wind and rain squalls than those which pass by the north.

What can be the cause of this constantly observed fact? When a typhoon passes to the north the veering of the wind is from north-northwest or north to northwest, west-southwest, southeast; while when it passes to the south the wind veers from northwest to north-northeast, east-southeast, south. If we now consider the geographical position of Manila we shall find precisely that the winds from north-northwest, north, and north-northeast come from the interior of Luzon; those from northeast and east have to pass over a large area of Luzon and over the mountain range which runs north and south through the island; the southeast and south-southeast are likewise land winds, and the south wind has to cross the mountain range of Sungay. These conditions are evidently not favorable for the saturation of the air with aqueous vapor and consequently are unfavorable for the formation of rain.

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[1] "Les Bases de la Met. Dynam.." 2e livraison. Paris, 1900. p. 176.

In opposition to this the winds from the northwest, west, and southwest come almost directly from the China Sea with very few obstacles; circumstances very favorable for their arriving on these shores saturated with aqueous vapor and under perfect conditions for copious precipitation of water, especially so as they are the only winds that can circulate freely with great rapidity.

These statements are corroborated by facts, for instance by the typhoons in May, 1895, and May, 1896, which both passed Manila twice, first to the south and shortly afterwards to the north of the city. The most violent winds and those which brought with them the heaviest rain were those coming from the third quadrant. The curve of the typhoon of May 10–19, 1896, which the reader will find in Part III, Chapter VII, shows this fact, but the typhoon of May, 1895,[1] and especially the tables given below, illustrate it still better. These tables have been prepared from all the cyclones which are on record as having been observed to pass in the neighborhood of Manila. On the one hand were grouped together all the storms which passed north of the city, with their wind directions and corresponding quantities of rain observed every three hours; on the other hand, in a similar manner, all the storms which passed south of the capital. Expressing the quantity of rain belonging to each direction of wind in percentages of the whole amount observed we obtain the following results:

I. TYPHOONS PASSING NORTH OF MANILA.

Directions of the wind.	Per cent of rain.
NNW-NW-WNW	1.3
WNW-W-WSW	32.5
WSW-SW-SSW	57.9
SSW-S-SSE	6.2
SE	2.1

II. TYPHOONS PASSING SOUTH OF MANILA.

Directions of the wind.	Per cent of rain.
NW-NNW	34.3
N	15.2
NNE	11.8
NE	3.5
ENE	2.4
E	20.3
ESE	4.9
SE-SSW	7.6

Bayombong offers another good example of the influence of topographical conditions. It lies in the interior of Luzon and is 830 feet above the level of the sea, being surrounded on all sides by mountains. The typhoons are noticeable here only when they pass by in close proximity. Finally we quote as instances the places lying on the west coast, and above all in the Province of Union, which are protected from the easterly winds, i. e., from those from northeast to southeast, by a large mountain range; while the winds coming from the China Sea and which have a free entry, i. e., those from the south-southeast, south, southwest, west, and northwest, bring with them by far the most rain.

The maintenance of the energy of the cyclone.—From what has been said we can deduce that the cause of the energy of a cyclone and its maintenance lies in the condensation of the vapor contained in the air which is drawn into the cyclonic movement. The air at the base of the cyclone streaming in from all sides toward the center, is in direct contact with the surface of the land or sea, and therefore has their temperature. In the Tropics this is high, especially so if the cyclones pass through higher latitudes (at any rate, it is always higher than the temperature of the upper strata of the air), and holds in suspension a very great quantity of vapor which has its origin in the abundant and rapid evaporation from the tropical seas which surround us. But as the air comes partly from the north, partly from the south, partly overland, and partly across the sea, it follows that neither temperature nor amount of moisture can be uniform throughout it. This difference in temperature and humidity, but above all, the rapid expansion of the air which is forced upward by the eruptive vehemence of the cyclones and hurled outward by the centrifugal force, produce, as natural consequences, the great condensations and precipitations which are so characteristic of the cyclones in the Tropics. The condensations and precipitations take all forms, from the most delicate and highest cirrus to the thick and low nimbus, and from the drizzle to the violent torrent of rain. The equivalent of heat which is set free through the continual and extensive condensations of the vapor causes the expansion, and energetically keeps up the rarefaction of the air, as well as the depression which is necessary for the rapid aspiration of new masses of air. The latter take the place of the former, they mingle with each other, rise, and are rarefied in their turn, and bring new masses of vapor with them, by the condensation of which some heat becomes again free, creating expansion and rarefaction anew. Hence the vapor supplies, we may say, the fuel for working the terrible machine of destruction.

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[1] Cf. "Boletin Mensual del Observatorio de Manila," 1895, pp. 136, 137.

The form and extension of the rain and cloud areas.—These regions do not always strictly coincide with one another, nor are they concentric with the area of low pressure. In the Tropics the latter sometimes lies behind the center of the zone of clouds and rain, while on other occasions, on the contrary, these centers will fall behind the vortex. In shape these areas are not circular, but nearly always elliptical, owing, doubtless, to the inequality in the velocities of the progressive movement of the cyclone and of the movement of the atmosphere in the higher regions of it.

Speaking in general, the cloud zone, although it is in some manner concentric with the rain area, is not coextensive with it, but is much larger. It appears as if it were necessary that the rain cloud have a certain depth in order to produce rain, and thus the more exterior parts of the cloud, formed more by the effect of lateral expansion than directly by the ascending currents of air, seem not to have sufficient depth to form rain. So that if we consider the mass of clouds as they successively appear, there first comes a layer of fog, then follows a light veil of clouds, which gradually thickens as the cyclone approaches, till it has developed into the dark heavy clouds from which pours the rain.

The clouds of the rain zone are not the only cloud formations in a cyclone; still earlier we meet various cloud forms which are generated by the ascending air current. A portion of the vapor is raised to great altitudes before becoming condensed; it appears then in the form of extremely fine threads which are transmuted to forms resembling feathery vanes, by the development of small partial whirls. These are the cirrus clouds which, as has already been shown, belong in the Tropics to the earliest signs of the existence of a cyclone. Another portion of the vapor which has been raised is condensed at various altitudes above the earth's surface, and assumes forms and movements such as have already been described in Chapter III.

The extension of the cloud zone is sometimes extraordinarily large; nevertheless it seldom stretches over a greater distance than 500 miles from the center; the average length of the major axis of the elliptical cloud zone may be taken as being 700 nautical miles. The rain zone is, as already mentioned, smaller, but it extends often further in the rear than in the front.

There still remains one point on which some lay great stress in studying the nature of a cyclone, namely the area of central calm, which is generally free from rain and even from clouds.

The eye of the storm.—It is a well-known fact that in the innermost part of some cyclones a region makes its appearance, in which light and variable winds and absolute calm prevail. In this region, but especially in the absolute calm, the rain of the cyclone, which comes down in torrents, ceases, and the clouds occasionally break up, so that the sun, or the moon and stars, become visible on the blue sky; for this reason the region has been called by some "the eye of the storm."

We find a description of a cyclone which passed over the Island of Antigua (Antilles) in 1681, in Dampier's work, "Voyages and Descriptions" (Vol. II, Part III, p. 69. London, 1705), and of a typhoon in the China Sea, in July, 1687, in another work of his, "A New Voyage 'Round the World" (Vol. I, p. 413. London, 1703). Capper describes a central calm in his "Observations on Winds and Monsoons" (London, 1801), during a cyclone which passed over Pondicherry, near Madras, in December, 1760; moreover, in a work by Thom (London, 1845), "An Inquiry into the Nature and Course of Storms," such an experience is narrated of the bark *Exmouth.* We shall add a few examples of a later date:

The first of these is taken from the log of the steamship *Inchulva.* When this steamer happened to be in the vortex of a cyclone on May 29, 1881, in the Arabian Sea, many land birds and butterflies fell on the ship, and the sky cleared so much that the sun's disk became visible through a veil of cloud, and what is still more extraordinary, about a dozen stars were also observed. On board the steamer *Taicheong* the clearing up of the sky was noticed in the calm region of the typhoon; the moon and stars became visible as the "eye of the typhoon" passed over the vessel, some birds fluttered over the deck and abaft the ship. During the calm the barometer fell as much as 1 millimeter (0.04 inch), the minimum being 725.6 millimeters (28.57 inches).

The calm region of the Manila typhoon on October 20, 1882, deserves our special attention. It has been observed by Fr. Faura[1]: At 11.46 a. m. we came, after a heavy squall from the west-northwest, into the center of the typhoon; the calm was not absolute, but relative; at the beginning we had revolving winds, with heavy squalls at intervals of 6 minutes. At 11.52 there was perfect calm for two minutes, then followed eight minutes of relative calm, with winds from southwest. The blue of the sky did not become visible, but it cleared up so much that there only remained a thick veil of condensed vapor. Nor was the belt which the bar of the typhoon formed around the horizon distinguishable, as this was occupied by a compact mass of nimbus, cumulus, and fracto-cumulus. We do not believe that the diameter—that is, the length of the chord in which we passed the center—was greater than 14 to 16 miles. It seems that even during the short time which it took the vortex to travel from Manila to Subic the diameter of the "eye" did not remain constant; because, while at Manila the duration of the calm was only eight to ten minutes, the same lasted a whole hour at Subic.

The sudden rise of the temperature and the decrease of humidity as evidenced by the curves of the respective apparatus, attract the greatest attention. The thermometer rose from 25° C. (77° F.) to 31.5° C. (88.7° F.), and the relative humidity fell from point of saturation to 43 per cent, a percentage which is but rarely observed here during April and May. Several persons told us that when they opened the window at the time of the calm it had to be closed immediately on account of the scorching air, or as they expressed it, "el aire quemaba."

Another fact to which we wish to call special attention, since later on it will prove useful when expounding the theory of these phenomena, is the behavior of the barometer. The minimum took place at 11.40 a. m.—that is, six minutes before the arrival of the relative and twelve minutes before that of the absolute calm—wherefore at the moment we thought ourselves much nearer the center than we were. When at 11.54 the second relative calm set in, the barometer commenced its rapid ascent, and at 2 p. m. it stood at 730 millimeters (28.74 inches) while the wind suddenly regained its former violence but was now blowing from southwest.

Fr. Faura reports on the calm region of another typhoon, which also passed over Manila in the same year (1882) on November 5. There were three well-defined regions or zones discernible in the center of the storm field: The central space, the absolute calm, had a diameter of only about 11 miles, but in Cavite and Imus it lasted for almost an hour. The air was very oppressive. From the observations it can not be seen whether the sky cleared up in Cavite fully. We may therefore assume that it remained covered by a light cirrus veil, since at Manila the blue of the sky was not visible. However, half an hour before the center reached Cavite the cirrus veil was observed to break, not in circular shape, but with a deformation in the east-southeast. The second zone had a diameter of about 22 miles. Manila remained in it for more than one and one-half hours. The calm was relative; there were light winds, interrupted by short intervals of absolute calm. The sky was covered with a thick veil which did not allow the rays of the sun to pass through. Above and in the veil there were many cirro-stratus clouds, all convergent toward the space of absolute calm. Now and then cumuli and fracto-cumuli made their appearance, but they soon vanished again as if pushed back by an invisible force. The third region was covered with many thick cumulus clouds, which became gradually denser and appeared to stop. They formed a very compact mass, which was marked off by a sharp black line, the limiting belt of the rain area of the typhoon. In this space heavy squalls prevailed, interrupted by light winds. The length of its diameter was about 32 miles. The duration in Manila, including that of the relative calm, amounted to two hours and forty minutes. A difference in the temperature and the humidity was noticed in this case, too, showing itself before and during the passage of the center. It was, however, not so striking as was the case during the typhoon of October 20.

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[1] "Ligeros apuntes sobre el huracan del 20 Octubre de 1882 á su paso sobre Manila," Apéndice á la publicación mensual del Observatorio de 1885.

Several other instances of vortical calms observed in the Archipelago are on record, though their descriptions are not so complete. "The phenomena belonging to the region of vortical calm manifested themselves at Manila and Cavite during the typhoon of May, 1881, and at San Fernando (Union) during that of August of the same year in a forcible and unmistakable way. At all three places the wind suddenly ceased, or at least relaxed to a faint breeze, the sky cleared up near the zenith, and although at Cavite during the May typhoon the sun did not succeed in breaking through, still its disk could be seen, veiled by only a thin layer of clouds. At San Fernando, however, in August, the stars could be perceived overhead. After the interval of calm the winds recommenced to blow fiercely, but in an opposite direction, and the sky became again covered as before."[1]

Besides those already mentioned, central calms were noticed at Tabaco in November, 1890, at Vigan in September, 1893, and in Aparri in November, 1894, and July, 1896. There can, therefore, be no doubt that calms do appear in the center of the tropical cyclones, whatever may be the case of those appearing outside the Tropics.

We quote from Eliot[2] the following important paragraphs:

> *The eye of the storm.*—One of the most remarkable features of the more severe cyclones of the Tropics is the area of very light winds, or absolute calm, in the center of the storm. Over this area the torrential rain of the hurricane ceases, and the clouds frequently break away, showing blue sky with the sun or the moon and stars. On account of its peculiar clearness this spot has received the name "the eye of the storm."
>
> The eye of the storm is a calm area varying very largely in diameter, but rarely exceeding 15 to 20 miles in diameter, characteristic only of the most violent class of tropical cyclones. Immediately outside this central area of these cyclones the wind is indescribably furious and the rain falls in torrents. The transition from the hurricane winds immediately outside the central calm area to the calm area is usually very sharp, the passage as a rule being a matter of a few minutes only. The eye is sometimes an area of light breezes, but more commonly of absolute calm, without rain, and often with blue sky. The cross sea, however, is very violent and dangerous. Birds, and sometimes butterflies, have been found in the center, usually in an exhausted state.
>
> Five detailed accounts have been selected of the weather and sea experienced in the calm areas of four different storms or cyclones in the India and China Seas and are given below. The first instance is that of a tug in the Calcutta cyclone of 1864.
>
> The *Alexandra* steam tug was at anchor off Saugor light-house on the early morning of the 5th. At 4 a. m. the wind shifted suddenly to northeast, blowing in furious gusts, accompanied by pelting sleet and seas over all. On coming head to wind the engines were set going at full power; about 8 a. m. or 9 a. m. it became suddenly calm, with a heavy, confused sea, the sun appearing at the turn for a few minutes. The calm interval lasted about three-quarters of an hour—the steamer's head to wind and the engines doing their best. During the calm, being apparently in the vortex of the hurricane, several land birds were falling about the decks, some dead. At the end of the calm a thick mist and heavy rollers seemed coming from northwest, accompanied by a moaning sound, which was immediately followed by a sudden blast from the northwest, throwing the steamer on her beam ends and burying her in a sheet of foam to the top of the funnel.

The second description is that giving an account of the passage of the ship *Idaho* through the calm center in a hurricane in the China Sea, September 21, 1869.

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[1] "Estudio Sobre los Baguios que cruzaron el Archipiélago Filipino en el Año 1881," by José Cano-Manuel y Luque, Madrid, 1884.

[2] "Handbook of Cyclonic Storms." Calcutta, 1900, p. 157.

> Suddenly the mercury rose (from 27.62″ to 27.90″), and with one wild, unearthly, soul-thrilling shriek the wind as suddenly dropped to a calm, and those who had been in these seas before knew that we were in the terrible vortex of the typhoon, the dreaded center of the whirlwind.
>
> Till then the sea had been beaten down by the wind, and only boarded the vessel when she became completely unmanageable, but now the waters, relieved from all restraint, rose in their own might. Ghastly gleams of lightning revealed them piled up on every side in rough, pyramidal masses, mountain high—the revolving circle of wind, which everywhere inclosed them, causing them to boil and tumble as though they were being stirred in some mighty cauldron. The ship, no longer blown over on her side, rolled and pitched, and was tossed about like a cork. The sea rose, toppled over, and fell with crushing force upon her decks. Once she shipped immense bodies of water over both bows, both quarters, and the starboard gangway at the same moment. Her seams opened fore and aft. Both above and below, men were pitched about the decks and many of them injured.
>
> At twenty minutes before eight o'clock the vessel entered the vortex; at twenty minutes past nine o'clock it had passed and the hurricane returned, blowing with renewed violence from the north, veering to the west. The ship was now only an unmanageable wreck.

The third account is from the log of the steamship *Inchulva* (which has been given previously, p. 57).

An experience of considerable meteorological importance, on account of the observations taken, was that at Manila, October 20, 1882. (For description see p. 57.)

The following is from a report by Capt. P. Duhme, master of the steamship *Taicheong,* of a hurricane experienced off Formosa, July 17, 1891:

> In order to avoid running straight into the center I had the ship headed northeast into the prevailing sea, which manœuver was executed without accident. At 11.15 p. m. the wind suddenly moderated and backed to north-northwest, the sky cleared, the moon and stars becoming visible, a few sea birds anxiously fluttered about the ship. Until 12 m. there was a gentle northwest breeze, and then the smoke from the smokepipe was suddenly driven from the southwest. The engine having worked slowly only for some time, I immediately rang full speed and brought the ship's head to southwest. The wind increased rapidly from southwest, the barometer rose, and about fifteen minutes after the almost calm region had passed the ship the southwest wind was blowing with indescribable violence. Under full power the ship headed southwest by south in comparative comfort and escaped all damage. The southwest wind decreased slowly.

These descriptions give a general idea of the winds, weather, and sea usually experienced in the eye of the storm.

The following six paragraphs give a summary of the available information relating to the calm center of cyclones in tropical seas.

(1) The central calm is most characteristic of tropical cyclones. It has seldom been reported from cyclones originating in temperate latitudes. Cyclones originating within the Tropics may, however, move poleward into the temperate zones carrying their characteristic center with them.

(2) As the storm center moves toward the observer, the wind is steady in direction, blowing nearly at right angles to the path of the storm. There is a heavy rain, usually accompanied by lightning and thunder. Just before the passage of the central calm the hurricane is at its height. Captains of vessels report the wind as indescribably furious. Everything on deck the wind can reach is blown to pieces. In several instances the boat at the weather davits has been torn from strong fastenings and carried clear over the ship. In short, we have reports of winds as severe as any vessel could live through, and beyond that we can only conjecture, from the great number of ships "last seen" near the storm center, how much more violent the hurricane may be.

(3) In the majority of cases reported the ship passes almost instantaneously from the most frightful hurricane into absolute calm. Occasionally, however, after the first abrupt lull, the wind dies away gradually, so that it may be ten minutes or more before there is a perfect calm.

(4) The calm is usually described as complete, making all allowance for effect of the contrast with the preceding gale, and there seems no reason to suppose that, in most cases, there is any appreciable motion of the air.

(5) The descriptions given previously in detail, including those of the *Alexandra* and *Inchulva,* mention the fact of the sun or stars being seen during the central passage. In other cases there was a thick haze during the calm. The clearing of the sky overhead, either wholly or partially, is one of the most marked features of the center. The heavy rain of the hurricane ceases and the sky clears either to pale-blue sky with the sun or stars visible or to a haze. Some characteristic reports are as follows:

A lull, the weather cleared up, with clear sky overhead, but round the horizon all dark.

The sun shone at intervals during the calm.

The wind suddenly moderated and backed to north-north-west, the sky cleared, the moon and stars becoming visible.

(6) **All reports agree that the calm center is, roughly speaking, the lowest point of barometric depression in the hurricane. As to how the barometer varies during the interval of the calm passage, the accounts are meager and unsatisfactory.**

The entrance into the calm region.—The transition from the region of the most violent winds into the calm may be a sudden one if the belt of the relative calm is but small, and a gradual one if it has a larger extension. The extent of this belt depends in great part on the amount of humidity which the rotating air contains, but above all on the inclination of the axis of the cyclone. (See Pl. 2.) If a locality is traversed, not by the center of this absolute calm but by a chord, the duration of the absolute calm will be either very short, as was the case in Manila on October 20, 1882, or a relative calm of longer duration will take place, as in Manila on November 5 of the same year and in other cases of which we shall speak later on.

The sea in the center.—Although the waves running mountain high in one direction cease within the vortex, the heaving of the waters which is most violent and in all directions, does not subside. The whole area has the aspect of a gigantic caldron with its contents boiling and seething, as eye-witnesses assure us.[1]

The appearance of the sky at the center.—Observations have disclosed the fact that during the passage of the center the sky clears up considerably, either altogether, so that the sun, or the moon, and stars, become visible, or else that the sky is only covered by a thin veil of cloud. No doubt, the more or less complete clearing of the sky depends mainly on the distance at which the actual center passes, or on the duration of the absolute calm. If a relative calm passes over a place it will be noticed that the sky is much clearer in the direction of the center than in other directions. This has been proved by Fr. Faura's observation at Manila, when the absolute calm reached Cavite on November 5, 1882. (See p. 57.)

Temperature during the calm.—The figures given for the temperature in the regions of relative and absolute calm, or in the eye of the cyclone, appear to be contradictory. On the one hand, the temperature at Manila rose suddenly—it had been almost steady for some time previous to the passing of the center—on October 20, 1882, from 25° C. (77° F.) to 31.5° (88.7°), and fell again just as quickly after the passage of the center. On the other hand, the thermogram of November 5 took an entirely different form. The temperature remained low during the forenoon, before the calm, but it rose fairly quickly even before the center reached the meridian of Manila, remaining higher for some hours. The maximum was, as usual, observed at 2 p. m., and accordingly more than four hours after the center had passed. Again, in the passage of the vortex of a cyclone observed on steamship *Weimer,* October 5, 1891, scarcely any change in temperature took place, nor did the sky clear up. In Albay, also, during the passage of the cyclone of November 16, 1891, no noteworthy change in the temperature was observed. During the typhoon which traversed Vigan in the night of September 30, 1893, the barometer fell, indeed, to 727 millimeters (28.62 inches), but the thermographic curve during the relative calm, which was of long duration, showed a rise of less than 1° C. and the hygrometer curve showed no change worth mention. In Aparri no material change of the temperature was noticed when the centers of the typhoons of November 17, 1894, and of July 28, 1896, passed that place.

The barometer during the calm.—This subject has already been treated of in Chapter IV, but the question when the barometric minimum occurs and the precise moment when the barometer begins to rise again, offers special interest, as on these points we find in several authors records which be believe to be certain, and which, yet, are apparently contradictory. For although it be true that, generally speaking, all meteorologists agree in saying that the minimum takes place in the region of calm, still when we examine the different records published, we find a great variety as to the exact moment of the minimum and the rise. This variety probably arises from not taking continuous observations during the passage of the vortex, but only at intervals of more or less duration. To decide this question it is therefore necessary to examine only those cases in which a barographic curve was obtained during the passage of the vortex.

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[1] A. Schück, "Die Wirbelstürme." Oldenburg, 1881, p. 53.

Besides the three diagrams which Ballou reproduces in "The Eye of the Storm,"[1] the Manila observatory is in possession of barograms and thermograms by means of which we can fix the passing of the center. These were the cyclones of November 5, 1882, at Manila; of November 16, 1891, at Albay; of November 17, 1894, at Aparri; of September 30, 1893, at Vigan; of July 28, 1896, at Aparri, and of October 9, 1896, in Vigan. To these must be added those mentioned by Ballou on September 22, 1885, at False Point (India): of October 20, 1882, at Manila, and on August 18, 1891, at Saint Pierre (Martinique).

In the following table we have set down the respective data, and to these are added some other elements of importance for the study of tropical cyclones:

No.	Date.	Station.	Barometer (minimum).	Rise of the barometer.		Force of wind.	Probable inclination of axis.
				Slow.	Quick.		
1	Sept. 22, 1885	False Point	At the beginning of the calm.	During the calm.	Ten minutes after the calm.	Twice as strong after the calm.	Toward the rear.
2	Oct. 20, 1882	Manila	Two minutes before the relative calm.[1]		Immediately after the absolute and during the relative calm.	Before and after the calm, of equal force; previously more uniform.	Toward the front.
3	Nov. 5, 1882	do	At the beginning of the relative calm.		Long before the end of the relative calm.	Previously more violent.	Do.
4	Aug. 18, 1891	St. Pierre	At the beginning of the calm.		At the end of the calm.	Not ascertainable	Not known.
5	Nov. 16, 1894	Aparri	During the calm		do	Stronger after the calm.	Toward the rear.
6	July 28, 1896	do	Five minutes after the relative calm.[2]		Forty-five minutes after the calm.	Afterwards more violent.	Do.
7	Sept. 30, 1893	Vigan	Before the long relative calm.[3]		During the calm.	Of equal force; before the calm, more uniform.	Toward the front.
8	Oct. 9, 1896	do	At the beginning of the relative calm.	During the calm.	do	Gradually abating and getting stronger again.	Not known.
9	Dec. 16, 1900	14° Lat. N., 135° Long. E.	Before the calm; minimum, 26.16 inches.		do	Before and after the calm very violent.	Toward the front.
10	Aug. 2, 1901	26° 44′ Lat. N., 123° 2′ Long. E.	During the calm; minimum, 27.02 inches.		After the calm	do	Do.

[1] Barometer kept steady for eight minutes at the lowest point.
[2] Lowest reading of barometer kept on for thirty minutes.
[3] The barometer stood at the lowest point for a long time before beginning to rise again.

Thus we see that only in No. 2, No. 7, and No. 9 did the barometric minima set in before the calm. In these cases the axis of the cyclone had most probably an inclination to the front, which is shown by the duration of strong winds noticed before the center passed. But the inclination can not have been very great, for the winds had the same force previous to and after the calm, though they did not extend over the same area. We also find in these cases the extraordinary rapid rise during the relative calm.

In No. 6 only do we find the minimum and the rapid rise setting in after the relative calm, and as the cyclone showed no destructive effects, notwithstanding the low barometer of 716 millimeters (28.19 inches), and also as the winds were stronger on the rear of the center than on the front, we may assume that the axis possessed an inclination toward the rear.

In all other cases the minimum occurred in the calm, and the variety and irregularity which were observed during the time of the rapid rise seem to correspond to differences in the force of the wind, and hence to the inclination of the axis. In Case 1 the rapid rise took place after the calm. The winds were more violent afterwards, so that the axis had an inclination to the rear also. In Case 5 the rapid rise occurred toward the end and after the calm. The winds were stronger after the center had passed, the axis being, therefore, also in this case, inclined to the rear. In opposition to this we find in Case 3 the rapid rise commencing some time before the end of the relative calm. The winds were also stronger before the center had passed, so that we may conclude that the axis showed an inclination toward the front. As the barometrical minimum and the rapid rise took place in Case 8 during the relative calm, and the force of the winds was uniform previous to, and after, the passing of the center, we are not in a position to decide whether the axis had any inclination at all.

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[1] "The Amer. Met. Journal," 1892 to 1893, pp. 67, 121.

Notwithstanding the difficulty in reconciling the data just given, we do not hesitate to assert that there is a real connection between the hour of minimum and of the rapid rise of the barometer on the one hand, and the passage of the vortex and the inclination of the cyclone axis on the other. Only, since the inclination of the axis may vary greatly in different cyclones, and even in one and the same storm may be entirely different at different points in its track, it will give rise to innumerable modifications, which it will be impossible to reduce to a simple law. Although, however, we can not deduce definite relations between the factors mentioned, we can say that the inclination of the axis exercises no influence upon the *amount* of fall of the barometer.

SOME REMARKABLE MINIMA IN CYCLONIC CENTERS.

Millimeters.	Inches.	Date.	Locality.
687.33	27.06	Oct. 10–11, 1846	In Havana, Cuba. (West Indian Hurricanes, by E. B. Garriott, 1900, p. 58.)
709.93	27.953	Sept. 6, 1865	On Marie Galante, during the Guadalupe hurricane. (Monthly Weather Rev., Sept. 1898, p. 391.)
694.18	27.33	Feb. 5, 1870	On board H. M. S. *Farifa*, 500 miles to the west of Ireland.
694.23	27.332	Jan. 26, 1884	At Ochtertyre, near Crieff, Scotland. (Quart. Journ. of Royal Meteor. Soc., Vol. X., p. 114.)
689.23	27.135	Sept. 22, 1885	At False Point, Orrisa, India. (Nature, Vol. XXXV., p. 344.)
695.45	27.38	Dec. 8, 1886	At Belfast; probably about 27.28 inches (692.9 millimeters) over the north of Ireland. (Quart. Journ. Royal Met. Soc., Vol. XIII, p. 211.)
681.99	26.85	Aug. 18–19, 1891	At Morne Rouge, Martinique. (Quart. Journ. Vol. XVIII., p. 185. The hurricane over the West Indies, Aug. 18–19, 1891, by Francis Watts. (It is probable that the height of the barometer above sea level may not have been allowed for.)
704.85	27.75	Nov. 2, 1891	At a point 9 miles from Port Blair. (Handbook of Cyclonic Storms in the Bay of Bengal, by Eliot. Calcutta, 1900, p. 281.)
710.22	27.961	Apr. 29, 1892	Port Louis, Island of Mauritius. (The Mauritius Hurricane, April 29, 1892, by C. Meldrum; Quarterly Journal, Vol. XVIII., p. 205.)
703.95	27.717	Sept. 29, 1893	Near Tuguegarao, to the south, Island of Luzon, Philippine Islands.
693.98	27.323	Oct. 12, 1897	At Tanauan, Island of Leyte, Philippine Islands. (El Baguio de Sámar y Leyte, Observatorio de Manila, 1897, p. 66.)
628.91	24.76	Feb. 3, 1899	At Vohémare, Madagascar. (Annales Hydrographiques, No. 808, 2d serie, Vol. de 1899, p. 88.) The height of the station above sea level and the instrumental correction are nowhere to be found in the report.
723.39	28.48	Sept. 8, 1900	At Galveston. (The Galveston Hurricane, Monthly Weather Rev. for September, 1900; Washington, p. 371.) This reading was lower by 0.10 inch than any reading previously made at a station of the United States Weather Bureau.
694.95	27.36	Nov. 13, 1900	On Island of Guam, Marianas. (Boletin Mensual del Observatorio de Manila, 1900, p. 197.)
664.44	26.159	Dec. 16, 1900	About latitude 13° 35′ N. and longitude 134° 30′ E., on board the American S. S. *Arethusa*. (Boletin Mensual, 1900, p. 217, and Pilot Chart of the North Pacific Ocean, July, 1901, United States Hydrographic Office.)
686.51	27.028	Aug. 2, 1901	In latitude 26° 44′ N. and longitude 123° 2′ E. on board the S. S. *Laisang*.
713.23	28.09	Sept. 6, 1902	In latitude 32° 5′ N. and longitude 133° 25′ E. on board the U. S. A. T. *Sumner*.

Deductions.—The observations which have been secured during the passage of the center of some cyclones are so various and contradictory that they have led to opposing theories with regard to the inner organization of these systems. A close study of the extension of the central part, or of the eye of the cyclone, and the relations between that region and the height of the body of the cyclone may, however, some future time give us a clue to the explanation of such changeable and apparently contradictory facts.

Though the dimensions of the central area of absolute calm vary in different cyclones, we may take, nevertheless, the mean length of the diameter to be about 14 nautical miles. The height of the neutral plane (that is, the plane in which the two truncated cones spoken of on page 14 meet) above the surface of the earth hardly ever exceeding 5 nautical miles,[1] the diameter of the larger base of the lower conic frustum is scarcely three times the altitude. The smaller base differs not considerably from the lower. These conditions given, there appears no great difficulty in admitting that within this space of comparatively small height and great lateral extent occasionally air may be found in thermometrical and hygrometrical conditions which vary from those existing in the air found in the cyclonic movement itself, although the conditions are generally either identical or very similar.

When at noon on the 20th of October, 1882, Manila entered the central part of the vortex, the absolute calm, the temperature suddenly rose during its passage from 25° C. (77° F.) to 31.5° C. (88.7° F.), but fell again to its former level after the center had passed the city. This is a change which is exceptional, for no such rise was noticed either on the 5th of November, 1882, at Manila, or as far as we know, on any other occasion. It, therefore, attracted the attention of meteorologists and gave rise to various controversies, in which each one took the example to support his own particular views. (Compare "La Meteorología en la Exposición Colombina de Chicago," p. 58, and also "Über den Orkan vom October 20, 1882 zu Manila," in the "Zeitschrift der Österr, Gesellschaft für Meteorologie," 1883, p. 64; likewise Vettin "Experimentale Darstellung von Luftbewegungen" in "Meteorol. Zeitschr., 1884, p. 275.) Faye also made use of this change of temperature to prove the existence of descending air currents in the interior of cyclones.

After a close examination of all the circumstances we will find that the temperature remained steady and comparatively low from 7 p. m. on the 19th till a little before the transit of the center—that is to say, during the time in which the rain squalls were almost incessant and the gusts of wind freshened until they reached the force of a cyclonic storm. This steady, low temperature is without any doubt to be ascribed to the showers and wind squalls. According to the regular oscillations of temperature on cloudy days the thermometer had to fall during the afternoon of October 19, since during that month the normal temperature for 7 p. m. does not reach 26° C. (78.8° F.). After that hour the temperature decreases very slowly to 24° C. (75.2° F.) at midnight and then remains fairly constant until 7 a. m. It is, therefore, nothing extraordinary if, from 7 p. m. of October 19 to 7 a. m. of October 20, the temperature remained slightly below 25° C. (77° F.). Usually, indeed, on cloudy days the thermometer rises between 7 a. m. and noon to 27° C. (80.6° F.), but during these hours on October 20 the winds were already more than brisk, the squalls frequent, the rain heavy and continually increasing until the entrance into the relative central calm. At this moment the dense covering of nimbus grew lighter, the squalls ceased, the winds calmed down, the sky became almost clear; Manila was within the extended region of vortical calm of about 14 to 16 miles' diameter. What wonder then, that without any other cause but solar activity from a sky nearly clear, by simple radiation, the temperature rose rapidly till it reached the normal height, which is 31.5° C. (88.7° F.), for a cloudless day in October? Furthermore, we should like to point out that it is no uncommon thing for Manila that the temperature remains one or the other degree below the normal during rain, especially if this is accompanied by brisk winds.

From the foregoing discussion of this particular case follows as logical conclusion that an isolated fact of this nature is not a safe foundation on which to establish—without further data obtained under less dubious conditions—special theories on the structure of cyclones. But the same can not be said with regard to the extraordinary reduction of the relative humidity during the passage of the center. An explanation of this phenomenon is in our opinion a very difficult matter, but we shall at least endeavor to reproduce the existing views on the subject. In the center of a cyclone two regions must be distinguished possessing an entirely different character: namely, the boundary zone near the most violent part of the cyclone, having variable winds, and the central space. Some meteorologists are of opinion that the air currents must *ascend* in the center. Others, again, say that they must *descend*. Both these views are erroneous if taken as a whole and without drawing any distinction between the two central regions. They are at variance also with all experience. The greater number of meteorologists believe the air current in the most violent part of the cyclone and in the boundary zone toward the absolute calm to be ascending. Facts which have been observed seem to justify this view. Apparently they do not correspond to the hypothesis that a descending air current exists.

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[1] Eliot, "Handbook of Cyclonic Storms," p. 171; Cyclone Memoirs III, p. 272.

Thus much about the central zone. But are there any air currents in the actual central space? And, if so, are they ascending or descending? Some authorities maintain that there is no movement whatever.[1] This view is supported by the fact that small birds, butterflies, leaves, and other light objects have been observed there. Others, again, believe in a slight descending current. This would tend to throw light on the changes of temperature and of relative humidity, and although those who believe that there exists no current whatever in the central zone have some reasons for doing so, we, nevertheless, uphold our own view in opposition to them; namely, that the rapid fall of the relative humidity is difficult to explain, because we are still in want of the observational material requisite for such investigations. According to Pernter[2] the extraordinary decrease in the relative humidity is simply a consequence of the extraordinary increase in the temperature.[3] Nevertheless, as the meteorologists who agree to this last theory do not agree in their explanations of the lowering of the relative humidity, and as there are not wanting reasons to explain it, even in the opinion of those who admit the currents in the region of absolute calm, we believe that it is difficult to establish this point, and repeat that the fact of the rapid descent in the relative humidity is very difficult to explain, owing to the lack of data.

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[1] Dallas, "Storms in the Arabian Sea."

[2] J. M. Pernter, "Zeitschr. der Österr. Gesellsch. für Meteorologie. 1883," p. 67.

[3] See "Les Bases de la Météorologie Dynamique," 4^{me} livraison. Paris. 1900. p. 75.

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CHAPTER VI. CONFIRMATION OF WHAT HAS BEEN SAID IN THE PRECEDING CHAPTERS.

We think we can not give a better confirmation of what we have said than by treating in this chapter of the distribution of some of the meteorological elements around cyclonic centers in Manila.

The following three tables illustrate this distribution as actually observed. Among meteorological elements we have enumerated the atmospheric pressure, the direction of the wind, the barometrical minimum, and the rain; and to these are added the bearing and the direction of the center at the time of observation. The footnotes explain anomalies or irregularities.

Practical deduction.—(1) The above data, as exhibited in the tables, offer us a certain proof for the convergence of the wind around the center, since there is no case in which they ceased to be convergent. Now, it is physically impossible that in every instance the topographical conditions were responsible for the convergence, as Manila has been in all possible positions with regard to the centers of typhoons.

(2) If we carefully examine the winds at Manila when the center is in the first quadrant, it will be noticed that the convergence of the winds will be all the greater the farther off the cyclonic center lies, and this is especially the case during the months of the third and the two last months of the second group. Hence the southwest winds blow much earlier than they should, in accordance to the rule for points 8, 10, and 12, and even for 14. The inclination of the track toward the north likewise exercises a very great influence upon the earlier appearance of these winds. The winds coming from the northern side show less convergence on the outermost part of the whirl during the months of the first group.

(3) It is worth notice that the time of the barometric minima due to cyclones generally coincides with that of the lowest readings of the barometer resulting from the normal daily oscillations, which in the tropics occur normally between 3 and 4 o'clock in the morning and evening. There is no exception to this rule worth mentioning unless we have a very low reading, say below 753 millimeters (29.65 inches).

Hence may be deduced a practical conclusion—that generally, if the hour of the normal minimum does not change considerably, the typhoon is far off. We say "generally," for it may happen that although a whirl passes at a reasonably short distance, still the usual hours of the barometrical minimum show no change. In such a case the barometrical minimum and the character of the fall will give us intimation as to the greater or less proximity of the center, in spite of its being unable to alter the time of the normal minimum. For instance, the barometrical minimum of 742.40 millimeters (29.23 inches) was observed at 3 a. m. on September 17, 1894; but the hours for the minimum and maximum had become deranged on the previous day and no rise occurred during the night. In connection with the rapid fall of the barometer this was certainly no ambiguous sign that a typhoon would pass close by. If we combine this assertion with the valuable rule which Fr. Faura advanced a few years ago, and which runs, "The intensity of a cyclone depends on the degree to which the daily barometrical curve is disturbed," we shall have no difficulty in understanding that a good observer can derive great help from his barometer, so as to be able to recognize approximately the first indications, the intensity, and the movement of the cyclone. We propose to treat this matter more at length in Part II.

The distribution of rain round a cyclonic vortex varies very much and differs greatly in different cyclones. Between 1879 and 1894 the greatest amount during a single day, 181.1 millimeters (7.13 inches), fell at Manila during the typhoon of November 16, 1891.

DISTRIBUTION OF SOME METEOROLOGICAL ELEMENTS IN TYPHOONS AT MANILA.

MONTHS OF THE FIRST GROUP.

Year, month, and day.	Hour.	Barometric minimum.		Direction of typhoon at time of minimum.	Bearing of the center at time of minimum.	Wind.			Rainfall during the passing of the typhoon.		
		Millimeters.	Inches.			Two hours before the minimum.	During the minimum.	Two hours after the minimum.	Millimeters.	Inches.	Days.
Dec. 12, 1881	5.00 a.m.	751.55	29.589	W. 12° N.	S.	NNW.	N.	E.	49.0	1.929	11-12
Dec. 18, 1886	3.00 p.m.	56.86	.798	W. 13° N.	E. 70° S.	N.	N.	N.	48.5	1.909	18-19
Dec. 4, 1889	2.53 p.m.	49.68	.515		(1)	NNW.	N.	NNW.	250.8	9.855	1-4
Dec. 23, 1891	2.10 a.m.	56.72	.793	W. 20° N.	S. 25° E.	NNW.	N.	N.	1.0	0.039	22
Dec. 6, 1893	3.05 p.m.	55.80	.756	W. 5° N.	S. 5° E.	NNE.	NNE.	NNE.			
Dec. 2, 1894	3.12 a.m.	56.00	.764	W. 75° N.	E. 3° N.	NNW.	NNE.	NNE.	77.3	3.045	1-2
Dec. 24, 1894	4.00 p.m.	57.39	.818	W. 20° N.	SW.	Calm.	WSW.	S.	28.5	1.122	23-27
Jan. 3, 1890	3.35 p.m.	55.65	.751	W. 7° S.	W. 70° S.	NNE.	ENE.	NE.	1.7	0.067	1
Jan. 14, 1893	4.00 p.m.	56.52	.785	W. 20° N.	S. 20° W.	W.	SE.	SE.			

[1] It bifurcated; one branch to the China Sea, the other to the Pacific Ocean.

MONTHS OF THE SECOND GROUP.

Apr. 26, 1885	4.00 p.m.	757.44	29.821	W. 30° N.	S.	E.	NNE.	NNE.	1.8	0.071	2
Apr. 18, 1887	4.00 p.m.	53.67	.678	W. 80° N.	N. 27° E.	SW.	SW.	SW.			
Apr. 29, 1890	4.00 p.m.	54.57	.708	W. 25° N.	S. 10° W.	WNW.	NE.	NE.	44.1	1.736	28-30
Apr. 2, 1891	4.00 p.m.	55.96	.762	W. 50° N.	E.	W.	SW.	SE.[1]			
May 24, 1881	1.30 p.m.	49.28	.500	W. 10° N.	SW.	N.	ESE.	ESE.	166.8	6.568	24
May 17, 1883	4.00 p.m.	55.72	.754	W. 14° N.	S.	SE. by S.[2]	E.	SE.	56.2	2.213	14-17
May 20, 1888	3.00 p.m.	55.02	.726	W. 75° N.	S. 10° E.	ENE.	ENE.	SE.			
May 21, 1891	2.50 p.m.	55.10	.729	W. 10° N.	SW. 11° W.	SSE.	SSE.	SSW.			
May 15, 1893	3.00 a.m.	46.17	.378	W. 60° N.	SE. 11° E.	N.	N.	NNW.	129.0	5.079	14-16
May 8, 1894	4.00 p.m.	53.41	.662	W. 50° N. W. 15° N.	ENE.[3] S.	NW.	SW.	SW.			
May 12, 1894	3.18 p.m.	53.82	.679	W. 36° N.	E. 1° N.	S.	WSW.	SW.	19.7	0.776	11-13
May 28, 1894	4.25 p.m.	54.48	.704	W. 20° N.	SW. 11° W.	E.	SE.	SE.	3.6	0.142	27-28
Oct. 11, 1880	7.00 p.m.	55.75	.755	W. 12° N.	N. 28° E.	SSW.	SW.	SW.	48.0	1.890	12
Oct. 12, 1881	3.00 p.m.	52.38	.622	W. 40° N.	NE.	WSW.	SW.	SW.	40.3	1.587	12-13
Oct. 20, 1881	4.00 a.m.	49.20	.497	W. 40° N.	N.	W.	WSW.	SW.	31.0	1.220	18-20
Oct. 26, 1881	3.00 a.m.	55.32	.738	W. 40° N.	NNW.	SW.	SW.	SW.	0.0	0.000	
Oct. 20, 1882	11.50 a.m.	27.75	28.652	W. 10° N.	N.	WNW.	WSW.	S. by E.	165.2	6.504	20
Oct. 28, 1888	12.00 p.m.	48.54	29.471	W. 25° N.	SW.	NNE.	ESE.	SE.	30.1	1.185	28-29
Oct. 8, 1886	2.00 p.m.	55.87	.758	W. 23° N.	N. 50° E.	Calm.	WNW.	WNW.	163.1	6.421	8-11
Oct. 5, 1887	2.00 p.m.	55.11	.729	W. 70° N.	NE.	W.	NW.	W.	153.2	6.032	4-6
Oct. 19, 1889	4.00 a.m.	53.93	.683	W. 12° N.	N.	SSW.	SW.	NNW.	105.8	4.166	18-19
Oct. 29, 1889	2.00 p.m.	51.03	.568	W. 5° N.	SSW.	N.	NNE.	E.	15.5	0.610	29
Oct. 1, 1890	2.35 p.m.	52.00	.607	W. 60° N.	NE.	SSW.	SW.	S.	14.0	0.551	1-2
Oct. 10, 1890	4.00 p.m.	54.16	.692	W. 50° N.	NE.	SW.	SW.	SW.	3.5	0.138	10
Oct. 19, 1890	3.30 p.m.	53.00	.646	W. 20° N.	SSW.	NW.	SSW.	SSW.	54.8	2.158	17-20
Oct. 9, 1892	4.48 p.m.	49.90	.524	W. 40° N.	NE.	SW.	WSW.	W.	26.6	1.047	7-8
Oct. 28, 1892	3.00 p.m.	53.00	.646	W. 15° N.	NE.	SSW.	SW.	SW.	0.0	0.000	
Oct. 6, 1893	3.30 p.m.	53.50	.666	W. 30° S.	N. 10° E.	WSW.	SW.	W.	2.3	0.091	7-8
Oct. 11, 1893	3.40 p.m.	54.75	.716	W. 80° N.	NE. by N.	WSW.	SW.	SSW.	28.8	1.134	11
Oct. 25, 1893	3.00 p.m.	56.90	.800	N. 30° E.	ESE.	WSW.	N.	NW.	8.5	0.335	27
Oct. 3, 1894	2.06 a.m.	48.10	.453	W. 24° N.	N. 25° E.	WSW.[4]	WSW.	SW.	66.9	2.634	1-3
Oct. 9, 1894	3.55 p.m.	56.62	.790	W. 20° N. W. 73° N.	W. 19° S. N. 77° E.	WSW.	SW.	SSE.	49.5	1.949	7-9
Oct. 15, 1894	3.30 p.m.	55.60	.749	W 71° N.	N. 84° E.	WSW.	SW.	SSW.	7.8	0.307	14
Oct. 4, 1896	6.35 p.m.	50.35	.542	W. 11° N.		W. by N.	W. by S.	WSW.	20.9	0.823	4-5
Oct. 9, 1896	3.40 p.m.	51.10	.571	W. 15° N.		W. by S.	WSW.	WSW.	6.3	0.248	9
Nov. 5, 1882	10.20 a.m.	35.60	28.961	W.	S.	WNW.	NNE.[5]	SE. by E.	93.6	3.685	4-6
Nov. 17, 1883	3.00 p.m.	52.88	29.641	W. 10° N.	SSW.	SE.	E.	ENE.	36.3	1.429	16-18
Nov. 18, 1884	10.00 a.m.	47.75	.440	W. 30° N.	N.	WNW.	WSW.	SSW.	96.9	3.815	18
Nov. 7, 1885	6.00 p.m.	48.93	.486	W. 35° N.	N. 20° E.	WNW.	W.	W.	35.9	1.413	7-8
Nov. 17, 1886	3.00 a.m.	53.18	.653	W. 40° N.	E. 5° S.	NNE.	N.	N.	0.0	0.000	
Nov. 27, 1887	2.00 p.m.	55.16	.731	W. 15° N.	W. 20° S.	ESE.	E.	E.	82.2	3.236	26-27
Nov. 4, 1889	3.00 p.m.	50.27	.539	W. 12° N.	SSW.	N.	NNW.	ESE.	124.4	4.898	3-4
Nov. 11, 1890	12.54 p.m.	43.50	.272	W. 20° N.	N.	WNW.	SW.	S.	183.0	7.205	[6]10-13
Nov. 13, 1891	5.10 p.m.	50.80	.560	W. 5° N.	S.	NNW.	NNW.	N.[7]	27.0	1.063	13-14
Nov. 16, 1891	8.20 p.m.	48.55	.471	W. 20° N.	SSW.[8]	N.	N.	NE.[9]	187.6	7.390	[10]16-17
Nov. 11, 1892	3.18 p.m.	56.02	.765	W. 20° N.	SW.	NNE.	E.	ENE.	29.1	1.146	11
Nov. 21, 1892	2.12 p.m.	48.90	.485	W. 60° N.	N. 80° E.	SW. by W.	NNW.	WSW.	6.1	0.240	20
Nov. 23, 1893	3.22 p.m.	55.75	.753	W. 15° N.	WSW.	ENE.	ESE.	E.	80.0	3.150	20-24
Nov. 2, 1894	2.45 p.m.	55.98	.764	W. 46° N.	E. 2° S.	SSW.	Calm.	S.	5.8	0.228	2
Nov. 6, 1894	3.50 p.m.	56.38	.779	W. 3° S. W. 15° S.	SSW. SE. by E.	SW.	WSW.	NW.	0.0	0.000	
Nov. 17, 1894	3.30 p.m.	54.10	.690	W. 7° S.	N. 10° E.	WSW.[11]	W. by S.	SW.	6.9	0.272	18
Nov. 1, 1895	3.25 p.m.	54.21	.693	W. 20° N.		WSW.	SW.	WSW.	36.0	1.417	2

[1] Wind coming from the second quadrant kept steady during the afternoon and throughout the following day.

[2] Wind on the previous day and early in the morning was from the first quadrant; during the afternoon and on the following day from the second quadrant.

[3] There were two typhoons, one in the Pacific Ocean and one in the Visayas. The first bearing and direction have reference to the typhoon in the Pacific.

[4] Up to that time the wind was blowing from the fourth quadrant.

[5] Relative calm.

[6] On the 11th alone 153 millimeters (6.056 inches) rain were observed.

[7] The wind blew from the fourth quadrant up to 7 p. m.; from that time till 2 a. m. from the first, and afterwards from the second quadrant.

[8] A second typhoon crossed the latitude of Manila on the 17th in the direction NW.

[9] At 11 a. m. the wind was already blowing from the second quadrant.

[10] On the 16th as much as 180.6 millimeters (7.111 inches) rain were registered.

[11] From 7 p. m. to 6 a. m. the wind was blowing from the first quadrant, and it then veered round to the third quadrant.

DISTRIBUTION OF SOME METEOROLOGICAL ELEMENTS, ETC.—Continued.

MONTHS OF THE THIRD GROUP.

Year, month, and day.	Hour.	Barometric minimum.		Direction of typhoon at time of minimum.	Bearing of the center at time of minimum.	Wind.			Rainfall during the passing of the typhoon.		
		Millimeters.	Inches.			Two hours before the minimum.	During the minimum.	Two hours after the minimum.	Millimeters.	Inches.	Days.
June 28, 1881	8.00 p. m.	749.49	29.508	W. 15° N.	N. 40° E.	WNW.	W. by N.	WSW.	318.6	12.347	27–30
June 29, 1887	3.40 p. m.	53.40	.662	W. 20° N.	N. 40° E.	WNW.	WSW.	SE.	14.1	0.555	29–30
June 10, 1888	5.00 p. m.	54.06	.688	W. 60° N.	W. 30° N.	SW.	SW.	SW.	15.5	0.610	10–12
June 14, 1888	4.00 a. m.	53.91	.682	W. by N.	N.	S.	SW. by S.	SSW.	179.0	7.047	14–19
June 15, 1890	2.20 p. m.	55.55	.747	W. 46° N.	WSW.	N.	ESE.	SSW.	50.1	1.972	13–15
June 25, 1890	4.05 p. m.	55.35	.739	W. 45° N.	NE.[1]	SSW.	SW.	S.	90.0	3.543	24–27
June 28, 1890	2.55 p. m.	56.45	.782	W. 30° N.	WNW.	SSE.	SSE.	SE.	28.9	1.138	28
June 25, 1892	2.45 p. m.	54.89	.721	W. 20° N.	SSE.	NNW.	N.	E.	20.4	0.803	25–27
June 28, 1894	3.00 a. m.	52.63	.631	N. 34° E. N. 10° E.	W. 77° N. N. 5° E.	SW.	SSW.	SSE.	165.3	6.508	[2]25–30
June 8, 1895	3.55 p. m.	55.80	.756	W. 25° N.		SW.	SW.	Calm.	34.7	1.366	7–9
June 6, 1896	3.00 p. m.	51.65	.593	W. 27° N.		NE.	E.	ESE.	81.6	3.213	5–7
July 8, 1881	5.00 p. m.	54.16	.692	W. 35° N.	W.	SSW.	SW.	SSW.	143.3	5.642	7–9
July 13, 1881	4.00 p. m.	51.27	.578	W. 50° N.	NE.	W.	WSW.	W.	12.0	0.472	12–14
July 10, 1882	3.00 p. m.	55.74	.755	N. 10° E.	W.	S.	SE	SE.	41.2	1.662	8–12
July 16, 1882	7.00 a. m.	53.53	.667	W. 16° N.	NNW.	SW.	E.	SSW.	135.7	5.343	14–18
July 10, 1883	5.00 p. m.	50.64	.554	W. 25° N.	N. 31° E.	W.	SW.	SW.	42.8	1.685	11
July 24, 1883	4.00 p. m.	53.50	.666	W. 72° N.	W. 30° N.	SSW.	SSW.	SSW.	103.6	4.079	21–25
July 5, 1884	4.00 a. m.	54.34	.699	W. 15° N.	W. 45° N.	S.	S.	SSW.	6.8	0.268	4–6
July 10, 1884	4.00 p. m.	50.22	.537	W. 70° N.	N. 20° E.	SW.	SW.	WSW.	58.3	2.295	9–12
July 27, 1884	2.00 p. m.	49.69	.516	W. 30° N.	N.	SW.	SW.	WSW.	37.6	1.480	26–28
July 16, 1885	3.00 p. m.	55.66	.751	W. 60° N.	N. 26° E.	SW.	WSW.	WSW.	64.1	2.524	16–18
July 8, 1887	4.00 p. m.	56.01	.764	NW. by W.	SW. by S.	ESE.	E.	ESE.	10.1	0.398	7–9
July 19, 1887	5.00 a. m.	53.47	.665	W. 70° N.	ENE.	SW.	SW.	SW.	294.6	11.599	18–22
July 24, 1887	4.00 p. m.	53.79	.678	N. by W.	NNE.	SW.	SW.	SW. by W.	8.9	0.350	23–26
July 8, 1888	4.00 p. m.	54.13	.691	W. 10° N.	WSW.	SW. by S.	SW.	SSW.	44.5	1.752	5–7
July 14, 1888	3.00 p. m.	47.60	.434	NW.	N. by E.	SW. by S.	SW.	SW. by S.	90.2	3.551	10–15
July 21, 1888	4.00 p. m.	53.40	.662	N. 60° E.	N. by E.	WSW.	WSW.	WSW.	47.2	1.858	18–22
July 16, 1889	3.00 a. m.	52.10	.611	W. 15° S.	NW.	SSW.	SSE.	E.	141.0	5.551	14–16
July 26, 1889	4.00 p. m.	55.84	.758	W. 10° N.	NNW.	SW.	SW.	SW.	8.9	0.350	24–27
July 12, 1890	4.00 p. m.	55.55	.747	W. 55° N.	NNE.	SW.	SW.	SW.	133.7	5.264	10–14
July 16, 1890	3.50 p. m.	54.15	.692	W. 80° N.	NNE.	NW.[3]	SW.	W.	315.4	12.418	15–16
July 29, 1890	3.12 p. m.	53.80	.678	W. 70° N.	NE.	SW.	SW.	WSW.	6.6	0.260	28–29
July 10, 1891	3.50 p. m	51.00	.567	W. 10° N.	NNW.	SE.	SSE.	SE.	84.4	3.323	9–11
July 16, 1891	4.10 p. m.	53.00	.646	W. 40° N.	ENE.	SW.[4]	WSW.	W.	43.0	1.693	17–19
July 26, 1891	3.00 a. m.	51.96	.605	W. 80° N. W. 30° N.	NNW.[5]	NNW.	NNW.	S.	276.2	10.874	15–16
July 17, 1892	2.45 p. m.	55.05	.727	W. 20° N.	NW.	WSW.	SW.	SSW.	17.7	0.697	16–18
July 22, 1892	3.58 p. m.	53.40	.662	W. 20° N.	NW.[6]	SW.	SW.	SW.	40.0	1.575	20–23
July 16, 1893	2.55 p. m.	53.73	.675	W. 30° N.	NE.	WSW.[7]	SW.	SW.	65.1	2.563	16–17
July 27, 1893	4.30 p. m.	55.00	.725	W. 80° N.	NNE.	SSW.	WSW.	SW.	39.8	1.567	28–29
July 7, 1894	3.45 p. m.	55.75	.755	W. 32° N.	W. 32° N.	SSW.	SSE.	SSW.	11.8	0.465	5–8
July 17, 1894	3.48 p. m.	54.75	.715	W. 45° N. W. 45° N.	W. 37° N. E.	WSW.	SSE.	SSE.	72.2	2.843	17–19
July 20, 1894	4.28 p. m.	55.93	.761	W. 56° N.	E. 4° S.	WSW.	WSW.	WSW.	13.0	0.512	20–21
July 30, 1894	3.12 a. m.	55.05	.727	N.	N. 77° E.	SW.	SW.	NE.	58.1	2.287	29–30
July 22, 1895	3.36 p. m.	53.67	.673	W. 44° N.		SSW.	SW.	SSW.	6.8	0.268	21–23
July 26, 1895	4.00 p. m.	56.13	.765	W. 29° N.		W.	SW.	SW.	56.9	2.240	25–27
July 28, 1896	2.20 a. m.	50.59	.552	W. 17° N.		SW.	WSW.	WSW.	30.6	1.205	27–29
Aug. 28, 1880	3.00 p. m.	53.10	.650	W. 16° N.	N. 80° E.	SW.	SW.	SSW.	119.5	4.705	27–29
Aug. 19, 1881	8.00 p. m.	49.45	.506	W. 50° N.	N. 68° E.	WSW.	WSW.	SW.	243.4	9.583	18–20
Aug. 16, 1883	4.00 a. m.	53.61	.670	W. 10° N.	N. 40° E.	WNW.	NW.	WSW.	56.5	2.224	15–18
Aug. 8, 1884	4.00 p. m.	52.13	.612	W. 30° N.	N. 60° E.	SSW.	SW.	SE.	47.0	1.850	1–4
Aug. 20, 1884	4.00 p. m.	50.07	.531	W. 45° N.	N.	SW.	SW.	SW.	45.7	1.799	19–20
Aug. 23, 1885	3.00 p. m.	52.50	.627	W. 45° N.	N. 31° E.	W. by S.	W. by S.	WSW.	23.9	0.941	22–25
Aug. 1, 1890	4.30 p. m.	54.55	.707			WSW.	SW.	W.			
Aug. 11, 1891	4.18 p. m.	53.30	.658	W. 58° N.	NE.	SW.	SSW.	NW.	10.8	0.425	9–11
Aug. 28, 1891	4.20 p. m.	53.52	.667	W. 70° N.	NNE.	SW.	SSW.	SSW.	125.6	4.945	20–22
Aug. 31, 1891	4.00 p. m.	53.10	.650	W. 60° N.	N. 5° E.	SW.	WSW.	SSW.	26.6	1.047	29
Aug. 19, 1892	3.30 p. m.	55.50	.745	W. 40° N.	SW. by W.	ESE.	SE.	E.	3.0	0.118	19–21
Aug. 12, 1893	3.48 p. m.	53.80	.678	W. 70° N.	ENE.	WSW.	WSW.	SW.	14.4	0.567	11–14
Aug. 2, 1894	4.12 p. m.	55.20	.733	W. 37° N. W. 19° N.	E. 72° N. E. 2° N.	SW.	WSW.	WSW.	7.7	0.303	3–4
Aug. 5, 1894	4.00 p. m.	55.45	.739	W. 82° N.	E. 37° N.	WSW.	SW.	SW.	43.8	1.724	5
Aug. 1, 1896	11.00 p. m.	53.35	.660	W. 18° N.		NW. by N.	ENE.	ENE.	44.1	1.736	1–2
Sept. 21, 1880	3.00 p. m.	49.97	.527	W. 45° N.	N. 15° E.	SW.	SW.	SW.	10.7	0.421	20–23
Sept. 6, 1881	4.00 p. m.	52.91	.643	W. 40° N.	N. 15° E.	WSW.	WSW.	WSW.	26.1	1.028	7–8
Sept. 24, 1881	3.00 p. m.	54.82	.718	W. 45° N.	N. 64° E.	SW.	SW.	SW.	8.8	0.346	23–24
Sept. 9, 1882	4.00 p. m.	52.70	.634	W. 55° N.	N. 35° E.	SW.	WSW.	SW.	45.4	1.787	9–11
Sept. 30, 1883	5.00 a. m.	51.64	.593	W. 20° N.	W. 50° N.	SW.	SW. by S.	SW.	30.0	1.181	29–30
Sept. 8, 1884	3.00 p. m.	50.76	.558	W. 45° N.	N.	W.	SW. by W.	WSW.	19.3	0.760	7–9
Sept. 20, 1884	5.00 a. m.	54.10	.690	W. 68° N.	NE.	W.	W.	W. by N.	9.7	0.382	20–21
Sept. 10, 1887	4.00 a. m.	49.22	.498	W. 45° N.	NNE.	SW.	SW.	SW. by W.	105.1	4.138	8–11
Sept. 16, 1887	4.00 a. m.	54.64	.711	W. 13° N.	N.	SW.	SW.	SSW.	97.0	3.819	15–16
Sept. 19, 1887	3.00 p. m.	48.01	.449	W. 18° N.	N.	SW.	SSW.	S.	370.1	14.571	18–20
Sept. 24, 1887	3.00 p. m.	48.39	.465	W. 22° N.	N.	SW. by W.	WSW.	WSW.	8.5	0.335	24–25
Sept. 30, 1887	3.00 p. m.	52.73	.635	W. W. 20° N.	NW. W. 30° S.	SSW.	SSW.	SSW.	4.7	0.185	29–30
Sept. 27, 1888	5.00 a. m.	51.15	.573	W. 10° N.	N.	SW.	WSW.	WSW.	7.2	0.284	26–27
Sept. 23, 1889	4.00 p. m.	54.16	.692	W. 45° N.	W. 12° N.	Calm.	SSW.	E.	1.0	0.039	23

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[1] There was a second typhoon at 4 p. m. on the 25th in the NNW.

[2] Two typhoons at the same time, one in the Pacific, the other in the China Sea; the figures refer to the latter.

[3] NW. wind till 1 o'clock.

[4] In the morning the wind frequently from the fourth quadrant.

[5] The typhoon bifurcated.

[6] There was a second typhoon in the Pacific; it was to the NE. of Manila at noon on the 22d.

[7] The wind blew during the whole morning from the first and fourth quadrants; at 11 o'clock it veered round to the third quadrant.

DISTRIBUTION OF SOME METEOROLOGICAL ELEMENTS, ETC.—Continued.

MONTHS OF THE THIRD GROUP—Continued.

Year, month, and day.	Hour.	Barometric minimum.		Direction of typhoon at time of minimum.	Bearing of the center at time of minimum.	Wind.			Rainfall during the passing of the typhoon.		
		Millimeters.	Inches.			Two hours before the minimum.	During the minimum.	Two hours after the minimum.	Millimeters.	Inches.	Days.
Sept. 5, 1890	4.20 p.m.	752.50	29.627	W.	N. 5° W.[1]	SW.	SW.	SW.	54.5	2.146	4–7
Sept. 10, 1890	3.30 p.m.	55.25	.735	W. 80° N.	NE.	SW.	SW.	SW.[2]	66.8	2.630	8–12
Sept. 21, 1890	2.55 p.m.	54.15	.692	W. 20° N.	SSW.[3]	W.	SE.	E.	56.2	2.213	22
Sept. 29, 1890	5.10 p.m.	47.06	.412	W. 35° N.	NE.	SW.[4]	SSW.	SSW.	159.3	6.272	27–30
Sept. 10, 1891	3.15 p.m.	53.30	.658	W. 20° N.	NNE.	SW.	SW.	SSW.	27.7	1.091	9–10
Sept. 15, 1891	2.05 p.m.	54.00	.668	W. 40° N. W. 60° N.	SSW.[5] NNE.	WSW.	WSW.	NNE.	57.1 115.8	2.248 4.560	14–16 15
Sept. 20, 1891	4.40 p.m.	55.50	.745	W. 40° N.	NNE.	WSW.	W.	SW.			
Sept. 6, 1892	4.42 p.m.	50.28	.539	W. 15° N.	ENE.	WSW.	NW.	SW.	114.2	4.496	5–7
Sept. 16, 1892	2.54 p.m.	55.00	.725	W. 35° N.	NNE.	SW.	SW.	SW.	109.3	4.303	14–17
Sept. 1, 1893	3.00 p.m.	53.00	.646	W. 80° N.	NNE.	SSW.	S.	WSW.	62.2	2.449	([6])
Sept. 6, 1893	3.00 p.m.	53.10	.650	W. 20° N.	N.	SW.	SSW.	S.	194.5	7.658	4–6
Sept. 11, 1893	3.50 p.m.	53.20	.654	W. 80° N.	NNE.	SW.	SW.	S.	16.7	0.658	10–11
Sept. 26, 1893	3.45 p.m.	50.30	.540	W. 40° N.	NNE.	SW.	SW.	SW.	24.1	0.949	25–27
Sept. 30, 1893	4.20 p.m.	46.50	.390	W. 25° N.	N. by E.	SW.[7]	SW.	SW.	38.9	1.532	([8])
Sept. 6, 1894	3.15 p.m.	54.80	.717	W. 50° N.	ENE.	W.[9]	W.	S.	81.7	3.217	4–9
Sept. 17, 1894	3.00 a.m.	42.40	.229	W. 45° N. W.	N.	SSW.	SSW.	S.	128.6	5.024	15–18
Sept. 23, 1894	3.40 p.m.	54.55	.707	W. 30° N.	N. by E.	SSW.	SW.	SSW.			
Sept. 28, 1894	1.35 a.m.	45.60	.355	W. 40° N.	E. by N.	W.	NW. by N.	SW.	110.4	4.347	27–28
Sept. 18, 1895	3.00 p.m.	53.76	.676	W. 22° N.	------------	WSW.	WSW.	SSW.	32.2	1.268	17–19
Sept. 24, 1895	2.35 p.m.	53.65	.672	W. 17° N.	------------	SW.	SW.	W.	4.0	0.158	24

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[1] There was a second typhoon in the Pacific at noon on the 5th, to the ENE. of Manila.
[2] On the morning of the 9th the wind blew from the first quadrant, and during the early hours of the 10th from the fourth quadrant.
[3] There was a second typhoon in the Pacific on the 21st, to the NNE. of Manila.
[4] Early on the 27th and the 28th the wind blew from the first and second quadrants, but on the 29th from the third.
[5] Two typhoons, one in the NE., the other in the SSW.
[6] August 31 to September 1.
[7] On the 29th till 1 a.m., and on the 30th, frequently the wind blew from the first and fourth quadrants.
[8] September 29 to October 1.
[9] Till 11 a.m. the wind from the first quadrant: at 5 p.m. the wind veered round to the second quadrant, and on the 7th to the third.

CHAPTER VII. PROGRESSIVE MOVEMENT OF CYCLONES.

Causes of the progressive movement.—There are various causes which influence the progressive movement of typhoons. The principal one appears to be the general movement of the atmosphere in which they take place, however—not of that part only which directly overlies the land and sea over which they pass, but especially that portion of the atmosphere which moves at higher altitudes, as we are to look there for the seat of the greater part of the energy and power which nourishes and sustains the atmospheric whirls. This general movement carries the cyclones along with it in exactly the same manner as a river sweeps along the small eddies forming in it.[1] If the tropical cyclones move toward the west, or have at least a strong westerly component, it is doubtless because in the Tropics the general movement of the atmosphere is a westerly one, up to a great altitude. This is plainly illustrated on Plates XXX to XXXIII, Part II, Chapter II. In higher latitudes the cyclones are moving eastward and at a much greater velocity, because of the existence there of general easterly movement at all altitudes. The velocity is comparatively great, especially at the higher levels. The general movement of the atmosphere is caused by the disturbance of the thermal and barometrical equilibrium at the surface of the land, the seas, and the air strata at various heights, while the earth's rotation on its axis also exercises some influence.

The velocity of the progressive movement.—The velocity at which cyclones travel is different in almost every instance. It can no longer be doubted that the velocity increases with increase of latitude. In the following tables we have inserted those typhoons only the tracks of which are well known. We have divided them into four classes: (1) The cyclones which passed the meridian of Manila to the north; (2) those which crossed to the south; (3) those which passed to the west, and (4) those which passed by to the east. We have divided each class according to the groups of months in which the respective typhoons occurred:

I. TYPHOONS WHICH PASSED TO THE NORTH OF MANILA.

SECOND GROUP.

Month.	Day.	Year.	Mean velocity.			Direction while crossing the meridian of Manila.	Smallest distance of center from Manila (nautical miles).
			Nautical miles in twenty-four hours.	Nautical miles per hour.	Kilometers per hour.		
May	29–31	1884	270	11.2	20.7	W. 60° N.	40
Do	13–16	1893	160	6.6	12.2	W. 50° N.	13
October	12–13	1880	120	5.0	9.2	W. 6° N.	280
Do	12–13	1881	260	10.8	20.0	W. 35° N.	130
Do	18–20	1881	340	14.1	26.1	W. 17° N.	120
Do	24–25	1881	160	6.6	12.2	W. 22° N.	180
Do	19–21	1882	380	15.8	29.2	W. 20° N.	
Do	22–23	1883	260	10.8	20.0	W. 10° N.	220
Do	7–9	1886	180	7.5	13.9	W. 40° N.	50
Do	18–20	1889	340	14.1	26.1	W. 17° N.	20
Do	11–12	1890	190	7.9	14.6	W. 15° N.	200
Do	8–10	1892	270	11.2	20.7	W. 70° N.	230
Do	28–30	1892	200	8.3	15.4	W. 18° N.	130
Do	6–8	1893	220	9.2	17.0	W. 25° S.	350
Do	2–4	1894	190	7.9	14.6	W. 25° N.	80
Do	3	1896	------	8.0	14.8	W. 11° N.	120
Do	9	1896	------	6.0	11.1	W. 15° N.	130
November	17–19	1884	230	9.6	17.8	W. 30° N.	10
Do	6–8	1885	400	16.6	30.7	W. 45° N.	50
Do	19–20	1888	650	27.0	50.0	N. 49° E.	230
Do	10–12	1890	170	7.1	13.1	W. 9° N.	6
Do	16–18	1894	180	7.5	13.9	W. 9° S.	120

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[1] Ferrel, "A Popular Treatise on the Winds," London, 1890, p. 275.

I. TYPHOONS WHICH PASSED TO THE NORTH OF MANILA—Continued.

THIRD GROUP.

Month.	Day.	Year.	Mean velocity.			Direction while crossing the meridian of Manila.	Smallest distance of center from Manila (nautical miles).
			Nautical miles in twenty-four hours.	Nautical miles per hour.	Kilometers per hour.		
June	27–29	1881	260	10.8	20.0	W. 50° N.	80
Do	25–26	1884	250	10.4	19.2	W. 20° N.	70
Do	8–10	1891	190	7.9	14.6	W. 17° N.	210
July	14–15	1880	160	6.6	12.2	W. 11° N.	140
Do	14–16	1882	290	12.0	22.2	W. 14° N.	290
Do	9–11	1883	270	11.2	20.7	W. 22° N.	120
Do	3–5	1884	220	9.2	17.0	W. 15° N.	80
Do	9–11	1884	270	11.2	20.7	W. 70° N.	290
Do	26–27	1884	280	11.6	21.5	W. 30° N.	80
Do	15–17	1885	250	10.4	19.2	W. 60° N.	220
Do	13–14	1888	310	12.9	23.9	W. 45° N.	180
Do	19–21	1888	350	14.5	27.0	N. 55° E.	230
Do	14–16	1889	210	8.7	16.1	W. 25° S.	290
Do	25–27	1889	260	10.8	20.0	W. 80° N.	310
Do	11–14	1891	230	9.6	17.8	W. 4° N.	310
Do	17–18	1891	250	10.4	19.2	W. 7° N.	260
Do	24–27	1891	230	9.6	17.8	W. 74° N.	13
Do	25–30	1891	110	4.6	8.5	W. 58° N.	150
Do	30–31	1892	230	9.6	17.8	W. 8° N.	340
Do	16–18	1893	180	7.5	13.9	W. 33° N.	190
Do	27–30	1893	120	5.0	9.2	W. 50° N.	170
Do	26	1895	-----	14.0	25.9	W. 29° N.	200
Do	28	1896	------	13.0	24.0	W. 17° N.	230
August	28–29	1880	200	8.3	15.4	W. 15° N.	110
Do	19–21	1881	230	9.6	17.8	W. 52° N.	140
Do	25–26	1881	290	12.0	22.2	W. 48° N.	340
Do	16–18	1883	130	5.4	10.0	W. 10° N.	200
Do	19–20	1884	210	8.7	16.1	W. 20° N.	90
Do	1–3	1885	260	10.8	20.0	W. 30° N.	310
Do	22–24	1885	230	9.6	17.8	W. 33° N.	270
Do	26–28	1886	210	8.7	16.1	W. 11° N.	90
Do	15–17	1888	320	13.3	24.6	W. 30° N.	450
Do	22–25	1891	170	7.1	13.1	W. 47° N.	140
Do	3–4	1894	190	7.9	14.6	W. 10° N.	(?)
September	20–22	1880	250	10.4	19.2	W. 5° N.	130
Do	25–27	1880	190	7.9	14.6	W. 50° N.	260
Do	6–8	1881	260	10.8	20.0	W. 40° N.	350
Do	6–9	1883	160	6.6	12.2	W. 45° N.	40
Do	29–30	1883	270	11.2	20.7	W. 15° N.	50
Do	7–9	1884	140	5.8	10.7	W. 45° N.	80
Do	9–11	1887	250	10.4	19.2	W. 22° N.	290
Do	15–17	1887	280	11.6	21.5	W. 17° N.	220
Do	18–20	1887	250	10.4	19.2	W. 18° N.	70
Do	23–25	1887	320	13.3	24.6	W. 50° N.	130
Do	29–30	1887	180	7.5	13.9	W. 5° N.	10
Do	25–27	1888	270	11.2	20.7	W. 10° N.	230
Do	4–6	1890	180	7.5	13.9	W.	270
Do	28–30	1890	210	8.7	16.1	W. 25° N.	30
Do	19–22	1891	210	8.7	16.1	W. 34° N.	220
Do	5–8	1892	270	11.2	20.7	W. 17° S.	520
Do	15–18	1892	290	12.0	22.2	W. 31° N.	360
Do	22–27	1892	230	9.6	17.8	N. 62° E.	200
Do	5–7	1893	230	9.6	17.8	W. 28° N.	250
Do	10–12	1893	360	15.0	27.8	W. 44° N.	180
Do	18–20	1893	270	11.2	20.7	W. 62° N.	340
Do	26–27	1893	230	9.6	17.8	W. 27° N.	150
Do	(1)	1893	260	10.8	20.0	W. 18° N.	170
Do	14–15	1894	250	10.4	19.2	E. 7° N.	240
Do	16–17	1894	170	7.1	13.1	W. 45° N.	60
Do	23–24	1894	320	13.3	24.6	W. 38° N.	280
Do	26–29	1894	230	9.6	17.8	W. 40° N.	30
Do	18	1895		14.0	25.9	W. 22° N.	360
Do	24	1895	------	6.0	11.1	W. 17° N.	350
Mean				9.8			

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[1] September 30–October 1.

THE DIRECTION OF THE TRACK AND THE VELOCITY OF PROGRESSIVE MOVEMENT OF CYCLONES WHICH PASSED NORTH OF MANILA.

From the tables on pp. 70 and 71 we learn that no typhoon which crossed by the north of Manila belonged to the months of the first group. By far the greater part belongs to the third monthly group and the neighboring months. A few belong to November, but not a single one can be found in the third decade of this month.

The mean inclination of the track reaches its maximum at W. 30° N. in July. In August and September it does not go beyond W. 27° N. The average general velocity amounts to 9.8 miles per hour.

Three cyclones crossed the meridian of Manila after recurving. They exhibit a mean inclination of E. 35° N.; hence it follows that the cyclones which recurve have in the second branch a somewhat greater tendency to move northward than in the first.

II. TYPHOONS WHICH PASSED TO THE SOUTH OF MANILA.

FIRST GROUP.

Month.	Day.	Year.	Mean velocity.			Direction while crossing the meridian of Manila.	Smallest distance of center from Manila (nautical miles).
			Nautical miles in twenty-four hours.	Nautical miles per hour.	Kilometers per hour.		
December	10–12	1881	310	12.9	23.9	W. 15° N.	-----
Do	6–7	1884	100	4.2	7.8	S. 86° W.	170
Do	26–28	1884	140	5.8	10.7	S. 86° W.	120
Do	18–20	1886	170	7.1	13.1	W. 8° N.	170
Do	21–24	1891	180	7.5	13.9	W. 20° N.	130
Do	3–6	1892	220	9.2	17.0	W. 20° N.	470
Do	5–7	1893	230	9.6	17.8	W. 7° N.	260
Do	22–23	1894	230	9.6	17.8	W. 10° N.	470
January	2–4	1890	190	7.9	14.6	W. 14° S.	310
Do	26–27	1890	-----	-----	-----	W. 8° N.	-----
Do	11–13	1893	290	12.0	22.2	W. 30° N.	380
Do	11–17	1893	140	5.8	10.7	W. 17° N.	170
Do	3	1894	-----	-----	-----	W. 5° N.	-----
Do	12	1894	-----	-----	-----	W. 10° N.	-----
February	4	1894	-----	-----	-----	W. 32° N.	-----
Do	13	1894	-----	-----	-----	W. 11° N.	-----
March	2	1894	-----	-----	-----	W. 4° N.	-----
Do	7	1894	-----	-----	-----	W. 6° N.	-----
Do	13	1894	-----	-----	-----	W. 10° N.	-----
Do	14	1894	-----	-----	-----	W. 6° N.	-----

SECOND GROUP.

April	9–11	1882	380	15.8	29.2	W. 34° N.	210
Do	25–27	1883	310	12.9	23.9	W. 30° N.	120
Do	25–27	1885	220	9.2	17.0	W. 23° N.	160
Do	9–12	1886	140	5.8	10.7	W.	260
Do	28–30	1890	340	14.1	26.1	W. 22° N.	140
Do	5–7	1894	-----	-----	-----	W. 8° S.	570
Do	11–14	1894	-----	-----	-----	W. 5° N.	560
May	23–25	1881	160	6.6	12.2	W. 12° N.	10
Do	15–18	1883	80	3.3	6.1	W. 10° N.	80
Do	19–21	1883	160	6.6	12.2	W. 18° N.	160
Do	20–21	1891	210	8.7	16.1	W. 10° N.	140
Do	6–9	1893	260	10.8	20.0	W. 28° N.	130
Do	7–10	1894	130	5.4	10.0	W. 16° N.	130
Do	26–29	1894	250	10.4	19.2	W. 17° N.	100
October	23–24	1882	170	7.1	13.1	W. 30° N.	210
Do	16–17	1883	120	5.0	9.2	W	160
Do	28–29	1883	260	10.8	20.0	W. 22° N.	30
Do	15–16	1886	340	14.1	26.1	W. 5° N.	220

II. TYPHOONS WHICH PASSED TO THE SOUTH OF MANILA—Continued.

SECOND GROUP—Continued.

Month.	Day.	Year.	Mean velocity.			Direction while crossing the meridian of Manila.	Smallest distance of center from Manila (nautical miles).
			Nautical miles in twenty-four hours.	Nautical miles per hour.	Kilometers per hour.		
October	28–30	1889	320	9.6	17.8	W. 5° N.	60
Do	18–20	1890	180	7.5	13.9	W. 10° N.	120
Do	7–9	1894	210	3.7	16.1	W. 30° N.	120
Do	18–20	1894	150	6.2	11.5	W. 6° N.	360
November	7–8	1881	190	7.9	14.6	W.	230
Do	26–28	1881	350	14.5	27.0	W. 20° N.	220
Do	4–6	1882	230	9.6	17.8	W. 10° N.	10
Do	16–18	1883	170	7.1	13.1	W. 10° N.	70
Do	12–14	1884	190	7.9	14.6	W. 14° N.	160
Do	8–10	1887	220	9.2	17.0	W. 9° N.	290
Do	12–14	1887	190	7.9	14.6	W. 16° N.	400
Do	25–27	1887	340	14.1	26.1	W. 22° N.	160
Do	3–5	1889	210	8.7	16.1	W. 10° N.	90
Do	12–14	1891	230	9.6	17.8	W. 4° N.	70
Do	15–17	1891	260	10.8	20.0	W. 19° N.	50
Do	18–19	1891	230	9.6	17.8	W. 5° N.	130
Do	9–12	1892	290	12.0	22.2	W. 20° N.	390
Do	13–16	1892	130	5.4	10.0	W. 10° N.	290
Do	11–14	1893	190	7.9	14.6	W. 10° N.	180
Do	21–23	1893	230	9.6	17.8	W. 15° N.	130
Do	5–6	1894	140	5.8	10.7	W. 7° S.	250
Do	13–14	1894				W. 7° N.	340
Do	1	1895		6.0	11.1	W. 20° N.	215

THIRD GROUP.

June	23–25	1885	210	8.7	16.1	W. 20° N.	150
Do	29–30	1887	340	14.1	26.1	W. 27° N.	130
Do	24–26	1892	190	7.9	14.6	W. 18° N.	80
Do	12–15	1894	300	12.5	23.1	W. 32° N.	290
Do	8	1895		13.0	24.0	W. 25° N.	122
Do	6	1896		8.0	14.8	W. 27° N.	39
July	6–7	1881	160	6.6	12.2	W. 34° N.	200
Do	7–9	1887	320	13.3	24.6	W. 25° N.	230
Do	6–8	1888	190	7.9	14.6	W. 5° N.	60
Do	10–11	1891	310	12.9	23.9	W. 33° N.	70
Do	3–4	1894	210	8.7	16.1	W. 17° N.	190
August	16–18	1884	110	5.0	9.2	S. 60° W.	60
Do	20–25	1892	130	5.4	10.0	W. 10° N.	290
Do	1	1896		12.0	22.2	W. 18° N.	45
September	29–30	1881	220	9.2	17.0	W. 12° N.	30
Do	3–5	1883	100	4.2	7.8	W. 3° N.	50
Do	28–29	1887				W. 16° N.	
Do	29–30	1887	250	10.4	19.2	W. 22° N.	440
Do	7–9	1888	130	5.4	10.0	W. 5° N.	180
Do	14–16	1891	220	9.2	17.0	W. 40° N.	120
Mean				8.5			

The greater part of typhoons which cross the Archipelago south of Manila belongs, as is natural, to the first and second group. (Tables, pp. 72 to 73.)

The average inclination of the cyclones of the first group is W. 11° N.; that of the second W. 12° N. If we combine these values with the mean inclination of the typhoons crossing north of Manila (W. 27°) we obtain as the general mean inclination of typhoons crossing the meridian of Manila W. 17° N.

The average velocity of cyclones crossing south of the city amounts to 8.5 miles per hour, being therefore somewhat less than that of typhoons passing north. The velocity increases with the latitude; the inclination of the track toward the north seems also to increase with the latitude.

III. TYPHOONS WHICH PASSED TO THE WEST OF MANILA.

SECOND GROUP.

Month.	Day.	Year.	Mean velocity.			Direction while crossing the parallel of Manila.	Smallest distance of center from Manila (nautical miles).
			Nautical miles in twenty-four hours.	Nautical miles per hour.	Kilometers per hour.		
May	25–27	1884	160	6. 6	12. 2	W. 20° N.	50
Do	7–12	1891	250	10. 4	19. 2	W. 54° N.	320
October	10–13	1889	80	3. 3	6. 1	N. 10° W.[1]	190

THIRD GROUP.

June	13–15	1886	210	8. 7	16. 1	N. 25° E.[1]	490
Do	11–13	1888	130	5. 4	10. 0	W. 40° N.[1]	160
Do	14–16	1888	140	5. 8	10. 7	W. 20° N.	270
Do*	13–19	1890	120	5. 0	9. 2	W. 41° N.	390
Do*	26–27	1890	280	11. 6	21. 5	W. 18° N.[1]	180
Do	28–29	1890	170	7. 1	13. 1	W. 30° N.	290
Do*	6–10	1892	100	4. 2	7. 8	N. 22° E.	180
Do*	22–24	1894	180	7. 5	13. 9	W. 23° N.[1]	230
Do*	26–27	1894	180	7. 5	13. 9	W. 75° N.[1]	310
July	9–11	1882	130	5. 4	10. 0	N. 9° E.	250
Do	22–23	1883	170	7. 1	13. 1	W. 67° N.	310
Do*	14–16	1887	120	5. 0	9. 2	W. 70° N.	180
Do	19–21	1888	350	14. 5	27. 0	N. 55° E.[1]	230
Do*	18–21	1892	210	8. 7	16. 1	N. 32° E.[1]	260
Do*	22–25	1892	150	6. 2	11. 5	W. 22° N.	180
Do	12–13	1894	100	4. 2	7. 8	W. 44° N.[1]	250
Do*	20–21	1894	70	2. 9	5. 4	W. 30° N.[1]	270
Do*	24–25	1894	100	4. 2	7. 8	W. 30° N.[1]	260
August	14–15	1880	290	12. 0	22. 2	W. 45° N.	360
Do	11–13	1887	130	5. 4	10. 0	W. 35° N.	290
Do*	18–20	1893	320	13. 3	24. 6	W. 42° N.	340
Do	26–29	1894	130	5. 4	10. 0	W. 24° N.[1]	310
September	16–18	1886	250	10. 4	19. 2	N. 30° E.[1]	360
Do	22–23	1889	250	10. 4	19. 2	W. 45° N.	180
Do*	21–23	1890	270	11. 2	20. 7	W. 22° N.	130
Do*	9–11	1891	190	7. 9	14. 6	W. 17° N.[1]	210
Do*	9–10	1894	140	5. 8	10. 7	W. 11° N.[1]	230
Mean				7. 1			

[1] The typhoon took the given direction from the twentieth parallel of latitude.

DIRECTION OF THE TRACK AND THE VELOCITY OF THE PROGRESSIVE MOVEMENT OF TYPHOONS PASSING TO THE WEST OF MANILA.

In the above table there are fourteen typhoons which were formed in the China Sea under the influence of a simultaneous depression in the Pacific Ocean. They are marked with an asterisk. If we exclude from the list the cyclones which did not cross the parallel of Manila but crossed that of 20° N., there will still remain out of the twenty-two typhoons that between 1879 and 1894 formed to the west of the capital, sixteen which owe their origin to a cyclone in the Pacific. The greater part of those remaining falls in the years during which observations over the Pacific, in Yap, in the Carolina group, Samar, and to the Northeast of Mindanao were still scanty. Hence we may suppose that these cyclones likewise were formed while typhoons were already existing in the Pacific.

Practical deductions.—(1) Centers of depression formed in the China Sea, besides being of rare occurrence, owe their existence to a cyclone in the Pacific.

(2 and 3) Two other consequences of practical importance are deduced from the preceding table. The first is that between the years 1879 and 1894 not a single typhoon was formed in the China Sea during the months of the first group, and only very few in the months included in the second group. We can accordingly say that, if a typhoon is formed in the China Sea, this will almost always happen in the months from June to September, both included. The second consequence is that these cyclones very rarely originate further south than 10° N.

We have already mentioned that the mean velocity amounts to 7.1 nautical miles. To this we must add that, as a rule, it is very small during the formation of the cyclone and for some days afterwards.

After recurvature, the mean inclination of the parabolic track for cyclones moving northeastward is N. 29° E.; that is, their mean direction is toward northeast by north. The mean inclination of the track for cyclones turning toward the Asiatic continent is W. 40° N., thus being greater than for cyclones crossing the Archipelago. But the track of typhoons crossing the Archipelago turns more and more northward while they are advancing farther up into the China Sea, so that these typhoons have the same direction as the former when reaching the same spot of the ocean. The reason for any difference between these two classes of cyclones is thus attributable solely to their place of origin.

IV. CYCLONES WHICH PASSED TO THE EAST OF LUZON WITHOUT CROSSING THE ARCHIPELAGO.

FIRST GROUP.

Month.	Day.	Year.	Mean velocity.			Direction while crossing the parallel of Manila.	Smallest distance of center from Manila (nautical miles).
			Nautical miles in twenty-four hours.	Nautical miles per hour.	Kilometers per hour.		
December	30–1	1882	320	13.3	24.6	W. 45° N.	90
Do	3–5	1889	180	7.5	13.9	N.	30
Do	30–1	1892	170	7.1	13.1	W. 67° N.	1,270
Do	1–2	1894	100	4.2	7.8	W. 65° N.	650
January	14–15	1892	210	8.7	16.1	W. 63° N.	480

SECOND GROUP.

April	16–19	1888	260	10.8	20.0	W. 56° N.	180
Do	1–3	1891	320	13.3	24.6	W. 49° N.	400
May	29–30	1881	------	------	------	W. 37° N.	------
Do	10–12	1887	260	10.8	20.0	W. 60° N.	300
Do	25–27	1887	260	10.8	20.0	W. 45° N.	600
Do	6–11	1894	120	5.0	9.2	W. 49° N.	300
Do	10–15	1894	100	4.2	7.8	W. 47° N.	290
October	4–6	1883	90	3.7	6.8	W.	100
Do	20–21	1887	250	10.4	19.2	W. 60° N.[1]	560
Do	1–2	1890	130	5.4	10.0	W. 53° N.[1]	660
Do	16–19	1890	140	5.8	10.7	N. 37° E.	60
Do	8–12	1893	140	5.8	10.7	W. 78° N.	250
Do	25–27	1893	420	17.5	32.2	N. 32° E.	750
Do	8–10	1894	200	8.3	15.4	W. 78° N.[1]	1,270
Do	14–16	1894	90	3.7	6.8	W. 57° N.	600
November	16–18	1886	220	9.2	17.0	W. 42° N.	140
Do	16–20	1891	260	10.8	20.0	W. 41° N.	170
Do	20–22	1892	290	12.0	22.2	W. 56° N.	170
Do	2–3	1894	200	8.3	15.4	W. 75° N.	790
Do	8–9	1894	140	5.8	10.7	N. 10° E.	1,080

[1] The cyclone took the given direction from the twentieth parallel of latitude.

IV. CYCLONES WHICH PASSED TO THE EAST OF LUZON, ETC.—Continued.

THIRD GROUP.

Month.	Day.	Year.	Mean velocity.			Direction while crossing the parallel of Manila.	Smallest distance of center from Manila (nautical miles).
			Nautical miles in twenty-four hours.	Nautical miles per hour.	Kilometers per hour.		
June	27–28	1885	210	8.7	16.1	N. 12° E.[1]	290
Do	13–14	1886	90	3.7	6.8	N. 10° W.[1]	220
Do	5–8	1890	160	6.6	12.2	W. 65° N.	600
Do	25–27	1890	390	16.2	30.0	W. 57° N.	390
Do	3–6	1891	170	7.1	13.1	W. 62° N.[1]	340
Do	10–13	1891	190	7.9	14.6	W. 84° N.[1]	190
Do	7–10	1892	160	6.6	12.2	W. 54° N.	230
Do	24–27	1894	160	6.6	12.2	W. 46° N.	190
July	12–13	1881	230	9.6	17.8	W. 67° N.	230
Do	27–28	1882	170	7.1	13.1	W. 52° N.	240
Do	19–21	1887	230	9.6	17.8	W. 74° N.[1]	300
Do	10–14	1890	190	7.9	14.6	W. 36° N.	360
Do	13–15	1890	180	7.5	13.9	W. 47° N.	250
Do	27–31	1890	260	10.8	20.0	W. 46° N.	340
Do	27–31	1891	170	7.1	13.1	W. 74° N.[1]	280
Do	20–23	1892	270	11.2	20.7	W. 32° N.[1]	830
Do	9–11	1893	230	9.6	17.8	W. 85° N.[1]	260
Do	17–18	1894	110	4.6	8.5	W. 43° N.	340
Do	20–21	1894	170	7.1	13.1	W. 51° N.	320
Do	28–30	1894	160	6.6	12.2	W. 42° N.	390
Do	22	1895	------	5.0	9.3	W. 44° N.	300
August	7–12	1891	170	7.1	13.1	W. 33° N.	280
Do	19–21	1891	300	12.5	23.1	W. 73° N.	270
Do	28–30	1891	260	10.8	20.0	W. 31° N.	340
Do	14–16	1892	220	9.2	17.0	W. 52° N.	270
Do	23–26	1892	160	6.6	12.2	W. 40° N.	610
Do	7–8	1893	310	12.9	23.9	W. 76° N.	380
Do	12–14	1893	170	7.1	13.1	N. 5° E.[1]	210
Do	30–2	1893	130	5.4	10.0	W. 87° N.[1]	150
Do	1–2	1894	100	4.2	7.8	W. 21° N.	400
September	24–26	1881	310	12.9	23.9	W. 40° N.[1]	350
Do	7–9	1882	180	7.5	13.9	W. 55° N.[1]	290
Do	6–8	1886	270	11.2	20.7	W. 50° N.[1]	430
Do	1–4	1890	160	6.6	12.2	N. 1° E.[1]	700
Do	5–9	1890	100	4.2	7.8	W. 69° N.[1]	600
Do	10–13	1890	100	4.2	7.8	W. 80° N.[1]	660
Do	19–22	1890	140	5.8	10.7	W. 68° N.[1]	510
Do	3–8	1891	170	7.1	13.1	W. 49° N.	290
Do	8–13	1891	220	9.2	17.0	W. 24° N.	310
Do	27–30	1891	490	20.4	57.8	W. 50° N.[1]	600
Do	6–9	1892	200	8.3	15.4	W. 32° N.[1]	650
Do	4–5	1894	130	5.4	10.0	W. 47° N.	440
Mean				8.3			

[1] The cyclone took the given direction from the twentieth parallel of latitude.

VELOCITY OF THE PROGRESSIVE MOVEMENT AND THE INCLINATION OF THE TRACK OF CYCLONES WHICH PASSED EAST OF LUZON WITHOUT CROSSING THE ARCHIPELAGO.

The velocity of these cyclones amounts to only 8.3 nautical miles per hour; hence it is not as great as that of those of the same group which cross the Archipelago. The reason for this difference must be looked for in the fact that cyclones east of Manila recurve in higher or lower latitudes, according to the season. This fact also explains the much greater inclination of the track northward. The mean inclination of the cyclones during the months of the first group is W. 66° N., while cyclones of the same group which cross the Archipelago have an inclination of only W. 11° N. The mean inclination of the track of cyclones belonging to the second group is W. 55° N., and that of cyclones crossing the Archipelago is W. 12° N. The inclination of the track of cyclones belonging to the third group is W. 50° N. for cyclones from the Pacific, and for those crossing the Archipelago it is W. 16° N.

Important practical deductions.—The differences just enumerated are so great that from them we may draw a very important conclusion for practical purposes. If a ship meets a cyclone in the Pacific, the commander will have but little difficulty in determining by the approximate direction of the track whether the typhoon belongs to those of the Pacific, or whether it will cross the Archipelago. If he is to the northward of 9° N. and at some distance from the Archipelago, and notices that the track has an inclination of more than 40° to the north, he will be justified in concluding that the cyclone will not cross the Archipelago and that it will keep on drawing northward in order to recurve afterward to the north-northeast or northeast. This rule is all the more reliable the further the observer finds himself to the east of the Archipelago and the further he is to the north of the eighth or ninth parallel, or else if the northward inclination of the track is greater, supposing that his position is *nearer* to the Archipelago and he finds himself in *lower* latitudes. We say this rule is very important in practice, because the sailor has to work his ship one way if he knows that the cyclone has to recurve, another way in the contrary case.

The table gives three cyclones which had already recurved before passing the parallel of Manila. They belong to the months of the second group, in which the vortex of the parabolic track lies in low latitudes. Three other cyclones belonging to the third group of months were also already on the second branch of the parabola when they crossed the twentieth parallel. The mean inclination of the track of these six cyclones in the latitude of Manila is W. 74° N., which fact confirms what has already been said about the greater northward inclination of the tracks in the second branch of the parabolical track.

As the greatest mean velocity of cyclones does not exceed ten miles, it will not generally be difficult to protect a ship from the dangers due to the proximity of the center, if while still in the outer boundary regions of the cyclone we can determine the direction of the track and then lay down, according to the position of the ship, the course which will bring us out of the influence of the cyclone.

The increase in the velocity of the progressive movement in higher latitudes.—Two typhoons which Fr. Froc[1] studied carefully (of the 9th and 29th of September, 1897, respectively) may prove the assertion that typhoons move faster in higher latitudes. We can use with great advantage a number of observations made on board of several vessels with Richard's barographs, in order to fix the individual velocities. The typhoon of the 9th of September ought to have reached its curve on the evening of the 7th in about the twenty-sixth parallel of north latitude and east of Nafa. Its velocity abated there, as is usually the case, but only so as to enter the northeastern branch of the parabolical track with a velocity again increased. At 10 a. m. the center was most probably at a distance of 160 nautical miles from Kagoshima and of 260 miles from Nafa and Kochi. The position corresponds to 29° 10′ north latitude and 132° east of Greenwich. If we combine these observations with other data which are at our disposal concerning the track of the storm-field, this typhoon must have moved between 10 a. m. and midnight, or during the afternoon and evening, with a velocity of 26.1 nautical miles per hour in an almost northeasterly direction. With somewhat less accuracy we may lay down the velocity for the preceding day as being 12.5 miles per hour.

At 11 p. m. on September 8 the center was 50 nautical miles southeast of Oshima, or in 32° 15′ north latitude and 136° 20′ east of Greenwich. At 1.15 a. m. it reached 33° 32′ N. and 137° 5′ E. Thus we have for this period a velocity of 31 nautical miles per hour. The self-registering aneroid of the German cruiser *Prinzess Wilhelm* shows that the center passed at 5.45 a. m. about 35 miles to the northwest of Yokohama, or in 35° 48′ N. and 139° 10′ E. In four and one-half hours it had traveled 170 miles, corresponding to a velocity of 37 miles per hour.

The Central Observatory of Japan has determined the track of this typhoon: It ran over Cape Onmaje Saki, then along the west coast of the Suruga Gulf, and next between Fujiyama and Nomadsu, in a northeasterly direction. At 6 a. m. on September 9 the center was found to be north of Tokio and it reached the ocean at 7 a. m. near Mito. At 10 a. m. it passed Kinkasan, and at 8 p. m. Nemuro (in Yezo). Hence it follows that the velocity from Tokio to the thirty-eighth parallel was 47.5 nautical miles, and from the thirty-eighth to the forty-second parallel it was 51.2 miles per hour.

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[1] Froc. "The Typhoons of September 9 and 29, 1897." Zikawei, 1898; and "M. Z.," 1899, pp. 145–157.

According to excellent observations made on board of H. M. S. *Daphne,* Capt. A. Galloway, which was on a voyage from Hakodate to Petropawlowsk, the center reached Iturup 12.03 a. m. on September 10, this being the southernmost island of the Kuriles. After crossing these islands it traveled parallel with this group of islands as far as to the south of Paramischir.[1]

The following table shows the velocity of the movement of the typhoon on September 29, 1897:[2]

TRACK OF THE TYPHOON OF SEPTEMBER 29, 1897.

Date.	Time.	Locus of the center.	Direction.	Progress (miles).	Velocity (miles).	Remarks.
Sept. 27	10.00 p.m.	Between Naha and Ishigakijima.	NNW.		14.0	
Sept. 28	6.00 a.m.	27° 10′ N., 126° 15′ E	N.	115	14.4	Lightning in the SE. of S. S. *Hohenzollern.*
Sept. 29	8.30 a.m.	30° 25′ N., 128° 20′ E	NNE.	190	(1)	Typhoon recurving; lightning in the SE.
Do	1.00 p.m.	Near Nagasima	NE.	128	28.4	Passage between Nagasaki and Kagoshima.
Do	6.30 p.m.	Center off Sikoku	NE.	190	34.5	*Empress of China* anchored in the N. passage.
Do	10.00 p.m.	SSE. of Meaco	ENE.	150	37.5	
Sept. 30	12.30 a.m.	Suruga Gulf	ENE.	120	40.0	*Kaiser* and *Irene* south of Iwosaki.
Do	2.00 a.m.	SSE. of Yokohama	ENE.	62	41.3	*Sydney* harbored in Yokohama.

[1] Variable.

During the past year (1902) several such examples have occurred. On August 7 a cyclone center which was perfectly developed passed by the east of Formosa and at noon of the same day was in the parallel of Hokota (Marshall Islands), at noon of the 8th in that of Naha (Loochoos Island), at noon of the 9th close to the German cruiser *Hertha* somewhat to the north of the parallel of Oshima (Loochoos Island), at noon of the 10th very close to Nagasaki, and finally on the 11th it was in the Yellow Sea almost to the northeast of Tokio, close to the Island Hondo.[3]

The progressive increase of the velocity is given in the following table (see Pl. XIX):

Date (noon).	Position, latitude.	Direction.	Distance traveled.	Velocity in nautical miles per hour.
	°			
Aug. 7	23.0	N., N. by E.		(1)
Aug. 8	26.0	NNE.	180	7.5
Aug. 9	29.0	NE.	240	10.0
Aug. 10	32.4	NE.	303	12.6
Aug. 11	35.9	NE.	384	16.0

[1] Recurving.

The typhoon which crossed the eastern portion of Kiushiu on September 7, 1902, is another example. This typhoon ran 290 miles from the 5th to the 6th; more than 300 miles from the 6th to the 7th, notwithstanding its recurving, and finally 400 miles from the 7th to the 8th.[4] (See Pl. XVIII.)

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[1] Extract of Fr. Froc's pamphlet by Dr. P. Bergholz, "The Hurricanes of the Far East," p. 76.

[2] Fr. Froc, "The Typhoons of September 9 and 29, 1897." Zikawei, p. 26.

[3] Philippine Weather Bureau. Bulletin for August, 1902, p. 161.

[4] Philippine Weather Bureau. Bulletin for September, 1902, p. 199.

CHAPTER VIII. ZONE OF THE TRACKS OF CYCLONES.

Different classes of trajectories.—The study we are going to make in this chapter of the zones of the trajectories is based purely on experience of the cyclones whose tracks have been followed. We may divide the tracks into two classes, corresponding to the great division of cyclones—the trajectories of the cyclones of the Pacific and those of the China Sea. The cyclones of the Pacific are those which do not cross the one hundred and twenty-fourth meridian east of Greenwich, and China Sea cyclones are those which cross this meridian (which may be taken as the mean meridian of the Philippine Archipelago), or those which are formed in the China Sea.

TRACKS OF CYCLONES OF THE PACIFIC.

Mean inclination of the track.—In general, all these typhoons have a parabolic track. If we ascertain the mean inclination of the first branch of the parabola while crossing the latitude of Manila, the mean latitude of the vertex, and the mean inclination of the second branch we shall get the following table:

Month.	Inclination of the first branch.	Latitude of the vertex.	Inclination of the second branch.
		°	
December	NNW.	15–16	NNE.
January	NNW.	16–17	NNE.
February	NNW.	17–18	NNE.
March	NNW.	18–19	NE.
April	NNW.	19–20	NE.
May	NW. by N.	20–21	NE.
June	NW. by N.	21–22	NE.
July	NW. by N.	23–25	NE.
August	NW. by N.	25	NNE.
September	NW. by N.	24–22	NNE.
October	NW. by W.	21–19	NE. by N.
November	NW. by W.	18–16	NE. by N.

If we reduce the months to the three groups we shall have:

Group.	Month.	Inclination of the first branch.	Latitude of the vertex.	Inclination of the second branch.
			°	
First group	December January February March	NNW.	15–19	NNE.
Second group	April May October November	NW.	16–21	NE.
Third group	June July August September	NW. by N.	21–25	NE. by N.

We must mention that the mean inclination of the track is much greater when crossing the latitude of Manila than is the case in the first branch of the parabola. This becomes especially noticeable during the months of the first group, and the reason for it is that the latitude of Manila does not differ much from that of the vertex of the parabolas corresponding to the different months, especially in those of the first group.

THE TRACKS OF CYCLONES OF THE CHINA SEA.

The peculiarities of the tracks of cyclones belonging to the China Sea.—No cyclone belonging to the first group has a parabolic track, unless it recurves in the interior of the Asiatic continent. We may presume, but can not prove with the data at our disposal, that this may happen. Some typhoons of the second group have a parabolic track. Their point of recurvature lies in the China Sea to the south of the Formosa Channel; but as the first branch inclines less to the north than is the case with cyclones of the Pacific, it follows that their recurvature lies in lower latitudes.

The cyclones of June, July, August, and September, the months which have the name of "typhoon months," recurve much more frequently. During these months cyclones appear not only much oftener but they reach higher latitudes also. The parabolic tracks have characteristics similar to those of the cyclones of the Pacific belonging to the same group. We therefore confine ourselves to the tracks of typhoons of the China Sea which do not recurve, and follow them up from their origin until they reach the Asiatic continent.

GENERAL CHARACTER OF THE CYCLONE TRACKS OF THE THREE GROUPS OF MONTHS.

First group.—Cyclones of the months belonging to the first group retain their original direction, west by north, in the south of the China Sea; the storm centers of December and January reach the mainland in Cochin China or in South Annam; those of February and March somewhat farther to the north, and therefore almost exclusively in Annam.

Second group.—The mean direction of cyclones belonging to the second group in April and May is northwest by west; those of April reach the continent to the north of Annam, those of May pass over the Gulf of Tonkin and the Straits of Hainan, but toward the end of the month some of them strike the coast between Macao and the Straits of Hainan. The October storms, especially those of the first days, reach as far northward as Hongkong; the remainder strike the coast—in accordance with the advance of the season—farther south, so that some of them reach Asia to the south of the Gulf of Tonkin. The original direction of the cyclones in October is WNW.; the November storms have from the first a direction W. by NW., and reach the coast of Annam; most probably no cyclone has ever reached China during November.

Third group.—The cyclones of June move toward NW.; they reach the continent generally on the south coast of China, from Breaker Point to the Straits of Hainan; some recurve south of the Formosa Channel.

The cyclones of July have also a northwesterly direction at the first. They may be divided into three classes: Those of the first, like June storms, enter the continent by the south of China; those of the second class travel along the coast between Amoy and Shanghai, from whence a portion, taking a NNE. direction, recurve into the Yellow Sea; those of the third recurve abreast of Formosa and then take the direction of the Japan Sea.

The August cyclones have a NW. direction from their beginning. Generally speaking, they may be considered as belonging to the July class.

The typhoons of September, which originally move toward NW. by W., usually belong to the first or third class of July cyclones.

If we recapitulate what has been said, we shall find that the zone of origin for typhoons in December, January, February, and March lies between the fifth and twelfth parallels; they reach the mainland between those of the eighth and fifteenth.

The zone of origin for typhoons of the months of the second group lies between the sixth and seventeenth parallels; they land on the Asiatic coast between those of the twelfth and twenty-third.

Finally, the zone of the third group has its beginning between the eighth and twentieth parallels; the northern limit of the district where they strike the continent is 30° north; the southern limit is, however, 18° north.

In order to discover the laws to which the tracks of cyclones belonging to the Pacific and the China Sea are subject, it is of importance to examine the general physical conditions of the zones and those of the adjacent regions. In order to do this it will suffice to observe the general distribution of the principal meteorological elements, the atmospheric pressure, and the temperature in the Far East during the different seasons.

THE NORMAL POSITION OF THE ISOBARS AND ISOTHERMS DURING THE MONTHS OF THE FIRST GROUP.[1]

December.—During this month the great center of high pressure always present during the months of the cold season of the northern hemisphere to the north of China in the interior of the Asiatic continent is found rather high up north, sufficiently intense—774 millimeters (30.47 inches)—but not of very great extent if compared with the same elements of this center in the month of November. The isobar 760 millimeters (29.92 inches) passes through the Philippine Archipelago close to Manila, while on the other hand it approaches closer to the coast of northern Japan in proportion to the increase of the polar area of minimum pressure, which during the greater part of the year centers over the Aleutian Islands. The Pacific center of high pressure has been driven northward by an area of low barometer which developed to the south of Molucca Islands. Thus during the month of December Manila has a center of maximum pressure to the north-northwest, another of high pressure to the east-northeast, and one of low pressure to the south-southeast.

Beyond the thirtieth parallel of north latitude the decrease in temperature is over 1° C. (nearly 2° F.) per degree of latitude. Within the Tropics the distribution of the isotherms is still more uniform. (See Pl. XV.)

January.—The Siberian area of high pressure is now situated between the fiftieth and sixtieth parallels of north latitude and the ninety-fifth and one hundred and fifteenth meridians east of Greenwich, with a mean barometer of 780 millimeters (30.71 inches). The high area of the Pacific, showing a pressure of 766 millimeters (30.16 inches), is found between the twentieth and thirtieth parallels, north latitude, and slightly to the east of the one hundred and seventy-fifth meridian east of Greenwich, near the Sandwich Islands. There are two areas of low barometer levels, one south of the Aleutian Archipelago with 750 millimeters (29.53 inches) pressure, the other in the interior of Australia. (See Pl. IV.)

February.—The Asiatic or Siberian high area moves slowly southeastward during January and February, extending now between the forty-fifth and fifty-fifth parallels of north latitude and the one hundred and fifth and one hundred and twenty-fifth meridians east of Greenwich. The Asiatic end of the Pacific area of high pressure has also been slightly displaced toward east-southeast, so that the isobar 760 millimeters (29.92 inches) passes now through the middle of the Philippines. (See Pl. V.)

March.—The isobars which during February exhibited a tendency to approach each other in the southern part of the China Sea are during this month much closer together in the north, over Siam, Annam, and Tonkin. This is due to the progressive movement of a center of low pressure which from Ceylon, the Gulf of Manaar, and part of the coast of Coromandel, over which it lay during February, has shifted to the interior of British India. The Siberian center of maximum pressure, greatly diminished in intensity, has progressed toward east and embraces now part of western Manchuria. The Pacific high center has receded still more to the east-southeast, while the Pacific minimum area stretches from the western coast of Alaska along the entire group of the Aleutian Islands, passing south of them to about 170° east of Greenwich. (See Pl. VI.)

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[1] The twelve charts showing the normal distribution of isobars and isotherms in the Far East during the twelve months of the year are reproduced from "Revista Meteorológica," Manila Observatory, 1894, inches and degrees Fahrenheit having been added besides the decimal system of the originals.

Considering the progressive movements of the different centers mentioned during the first group of months we find that the Philippine Archipelago is, as it were, situated in a central area, around which revolve two areas of high pressure and two of low pressure. This accounts for the extraordinary regularity of the barometric variations observed all through the group, but especially at Manila, which consequently is in the most favorable position for observing the great atmospheric disturbances to which the Tropics are subject.

The tracks of cyclones of the first group (see Chart).—From what has been stated it follows that the tracks of cyclones of the Pacific occurring during the months of this group will lie along the boundary between the two areas of high pressure then existing, the one in the interior of the Asiatic continent, the other over the Pacific Ocean, and that they will be directed toward the polar center of low pressure, which occupies part of the Behring Sea. The typhoons of the China Sea travel through the lower latitudes, which under normal conditions are occupied by the outermost isobars belonging to the Siberian high area. It must be remarked that in the same measure as the area of high pressure moves back to the interior of Asia it loses its intensity from January to March; and furthermore as the outermost isobars advance northward the tracks become broader and endeavor to reach the center of low pressure which has been travelling north ever since January.

THE NORMAL POSITION OF THE ISOBARS AND ISOTHERMS DURING THE MONTHS OF THE SECOND GROUP.

April.—The area of high pressure, which during March lay to the north of China occupying part of Manchuria, extends now still farther north, but has so much diminished in intensity that the barometric column does not ascend higher than 764 millimeters (30.08 inches). At the same time the depression which during the past month prevailed in British India develops and advances eastward over the Strait of Malacca and the southern part of the China Sea, so that the isobar 757 millimeters (29.80 inches) occupies already a great part of Borneo, embracing also a portion of Celebes and the entire Java Sea. The isobar 760 millimeters (29.92 inches) forms the boundary zone between the Asiatic and the Pacific centers of high pressure and the depressions of Hindostan and of the Behring Sea, all of which develop and move around the zone comprising the Philippine Archipelago without ever encroaching upon it in such manner as to make it a center of either high or low pressure. (See Pl. VII.)

May.—The western area of low pressure has expanded itself more over the Continent, enveloping almost the whole region of the Himalayas and a good part of Thibet. Toward northeast it has developed in such a way that the isobar 754 millimeters (29.68 inches) extends over the whole of Hindostan and traversing the Gulf of Bengal embraces part of Siam and western China. The area of high pressure is confined to western Mongolia, so that in the interior of China the height of the barometer does not exceed 761 millimeters (29.96 inches); the south and east of China are enclosed by the isobar 757 millimeters (29.80 inches) and 759 millimeters (29.88 inches) respectively. The isobar 760 millimeters (29.92 inches) passes in the Pacific Ocean through western Polynesia at about the same distance from the Philippine Archipelago as the second isobar of the same value which runs from Mongolia through north Korea, thus serving as a limit between the high-pressure area of Mongolia and the Himalayan area of depression. The low-pressure area in the north lies far to the north of Yezo, stretching almost over the whole of Ochotsk.

Hence we find a low-pressure area to the west-northwest of Manila and a second one at twice the distance of the first to the north-northeast; the areas of high pressure are lying to the northwest and east-northeast. (See Pl. VIII.)

As inspection of the distribution of isotherms during this month will reveal the fact that on the eastern coasts of the Archipelago the temperature is much higher than in the interior and on the western shores. The highest temperature during May is found within a rather extended zone which stretches from the Marianas to the eastern coasts of the Philippine Archipelago, including also the western islands of the Carolina group.

October.—The India center of low pressure with 758 millimeters (29.84 inches) being about to disappear stretches its outermost isobars scarcely as far as Burma and northern Siam. Instead of it there develops over the interior of the Asiatic continent the area of maximum pressure characteristic of the cold months on the northern hemisphere, though its mean barometric height is only 767 millimeters (30.20 inches) during this month. The isobar 760 millimeters (29.92 inches), starting from Tonkin, crosses the island Hainan and then passes south of Formosa and along the southern and eastern coasts of Japan, serving as boundary zone between the high-pressure area of inner Asia and the low-pressure area of the polar regions, i. e., over the Behring Sea. The high-pressure area of the Pacific spreads very slowly in all directions.

Manila, therefore, has during this month one area of depression to the west-southwest and another to the north-northeast, while there is a center of maximum pressure north-northwest and one of high pressure to the east. (See Pl. XIII.)

After the month of September the temperature decreases rapidly north of the twentieth parallel of north latitude; but between this parallel and the equator there is very little change.

November.—The high-pressure area of inner Asia showing 770 millimeters (30.32 inches) develops rapidly in such a way that the isobar 760 millimeters (29.92 inches) passes through Luzon and envelops nearly the whole Asiatic continent, the most northern portion alone excepted. In consequence thereof the area of depression has vacated Hindustan and seems to confine itself entirely to a region not far from the southeast of Ceylon. The high-pressure area of the Pacific Ocean occupies a great part of the equatorial zone, extending to a considerable distance on either side of the line, while the northern area of low pressure has also developed, stretching now farther into the polar regions.

Manila has consequently during this month a center of maximum pressure to the north-northwest and one of low pressure to the west-southwest. Another center of high pressure is situated at a greater distance, extending from east to southeast, and a second center of depression lies from north-northeast to northeast. (See Pl. XIV.)

During the months of October and November the isotherms approach each other. In the Philippine Archipelago the temperature diminishes considerably, the mean thermometer readings of these months showing the greatest difference occurring between the mean temperature of any two consecutive months of the year.

The tracks of cyclones of the second group (see Chart).—The result of the various distributions of pressure centers described is that during April and May the cyclones of the Pacific Ocean move in a zone bounded by the extreme isobars of the two centers of high pressure lying over the Pacific Ocean and the Asiatic continent, respectively, while the cyclones of the China Sea have their trajectories to the south of the region corresponding to the isobar 760 millimeters (29.92 inches) of the inner Asiatic center of high pressure, said trajectories pointing invariably to the Hindustan center of depression.

In the same measure as the Asiatic high-pressure area develops from October to November, the typhoons of the China Sea are reduced to lower latitudes, their trajectories, however, always being influenced by the changes of position undergone by the Hindustan center of low pressure.

The cyclones of the Pacific, especially those during October, have their tracks in the immense region between the Philippine Archipelago, Japan, and the isobar 760 millimeters (29.92 inches) of the Pacific high-pressure area. During November this zone is somewhat narrowed by reason of the development of the Asiatic center of maximum pressure.

During all the months of the second group the typhoons of the Pacific move toward the polar depression.

THE NORMAL POSITION OF THE ISOBARS AND ISOTHERMS DURING THE MONTHS OF THE THIRD GROUP.

June.—The Asiatic high-pressure area lies now over a part of Siberia, having disappeared from the interior of China. The area of minimum pressure comprises Tibet and Turkestan; the isobar 755 millimeters (29.72 inches) runs from the south of Hindustan across the Gulf of Bengal and penetrates into China, which it envelops almost completely. The high area of the

Pacific has extended itself farther and shifts more to the north as the month draws to its close. A center of depression forms in Australia.

During the month of June Manila is, consequently, surrounded by three centers of low and one center of high barometer levels. Of the former the center of minimum pressure lies west of Formosa and northwest of Manila; to the south-southeast we have, at a much greater distance than the first, the low-pressure area in the interior of Australia; while a third depression, which we may call the polar, loses itself in the interior of the Bering Sea. The center of high pressure, of but small intensity, is situated in the Pacific to the northeast of Manila. (See Pl. IX.)

As to the isotherms the Archipelago is surrounded by a zone which has a somewhat more moderate temperature than that which prevails in the interior of the group, and what is true of the Archipelago in general in a measure holds good with regard to each of the various islands in proportion to its dimensions.

July.—The area of depression—746 millimeters (29.37 inches) has withdrawn westward; gaining in intensity. In the interior of Asia it lies at the extreme west of the Himalaya Mountains in the southwest of Turkestan. The isobar of 750 millimeters (29.70 inches) runs from Ceylon through the southern portion of the Gulf of Bengal, Siam, Cochin China, and the interior of China to the Yellow Sea, and from thence it reënters the continent. The isobar of 752 millimeters (29.60 inches) of the depression lying in the far north runs into northern Manchuria, and the outermost isobars of the other Siberian depression extend as far as Mongolia. The only widespread high-pressure area lies over the Pacific.

Thus the Archipelago is surrounded by three centers of low and one of high pressure. The area of the lowest pressure lies to the west-northwest of Formosa and to the north-northwest of Manila; the Siberian low-pressure area lies almost to the north of Manila, while the northern center of low pressure extends from northern Manchuria to the interior of the Bering Sea. (See Pl. X.)

Since the beginning of March the isotherms have changed their position to the north in such a way that the isotherm of 20° C. (68° F.) which in March extended from the Hainan Straits through south Formosa to the Pacific now runs by way of northern China, Korea, and the northernmost part of Yezo, almost parallel to the equator, into the Pacific. The thermometric gradient is generally greater over the continent than over the sea.

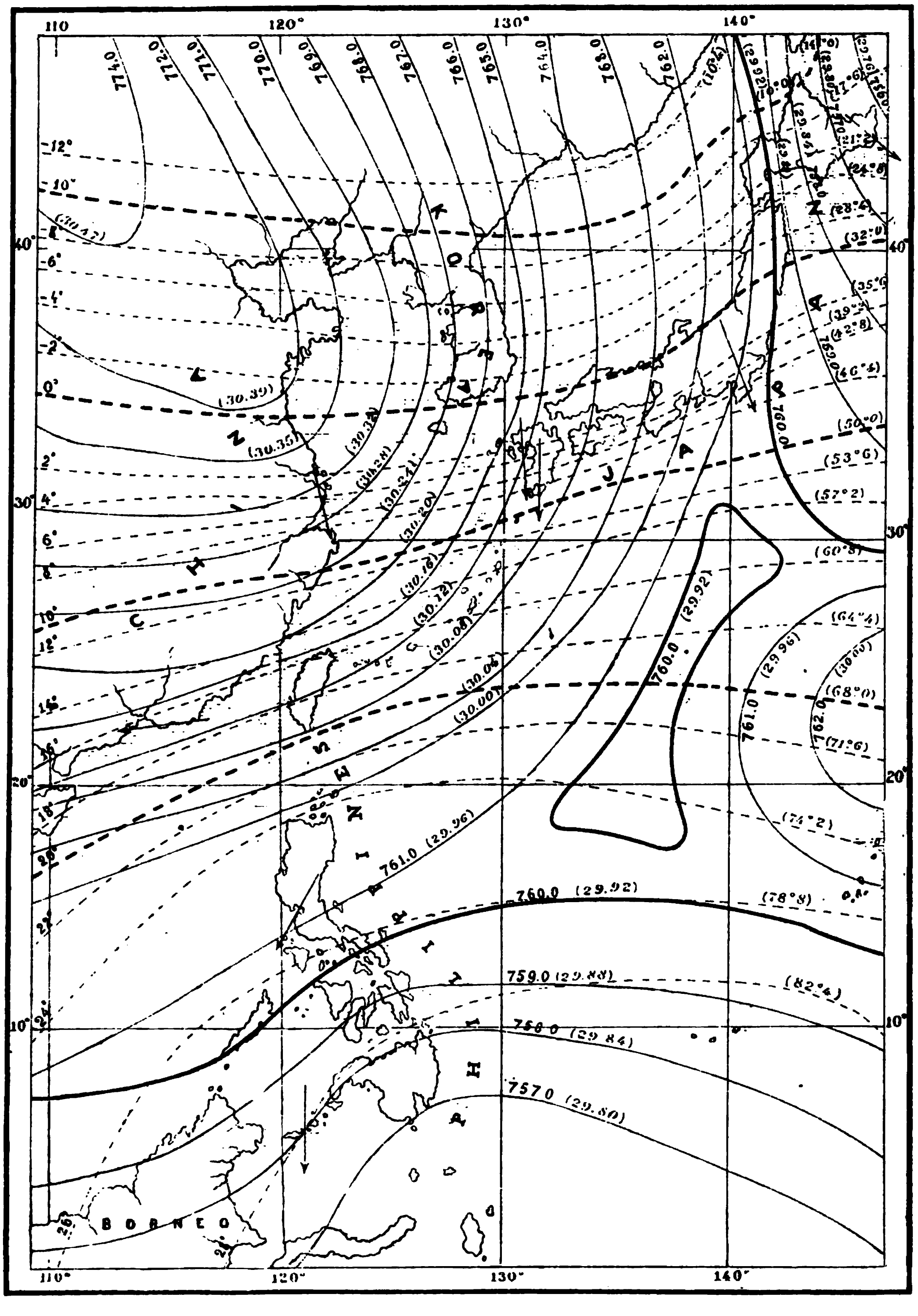
August.—Since July the Asiatic low-pressure centers have changed their place to the northwest; one low-pressure area is confined to the western part of the Himalayas and part of Afghanistan; the isobar of 755 millimeters (29.72 inches) does not extend any more beyond the China coast, but crosses Korea; the Siberian center has moved a great deal farther north. The northern center has shifted to the northeast, so that it can not send its outermost isobars any more as far as northern Manchuria. We find the high-pressure area of the Pacific almost in the latitude of the Island of Kiushiu (in the south of Japan). A center of low pressure lies, therefore, to the northwest of Formosa and to the north-northwest of Manila. The Siberian area of depression exercises hardly any influence on the Archipelago; the northern lies in the north-northeast. (See Pl. XI.)

The general conditions of temperature change but little from July to August in high latitudes, but somewhat more in the middle and lower latitudes. The temperature in the Archipelago, from the western part from Cape Bolinao to Isabela de Basilan and Zamboanga (in Mindanao) has a more moderate character. A zone of higher temperature, however, embraces a large portion of the Visayas and Mindanao. The highest temperature is found in Mindanao, as far as its shores are washed by the waters of the Pacific, about the Bay of Davao, and in part of the interior of Luzon as well as on the east coast.

September.—The intensity of the center of lowest pressure does not only diminish in its intensity but it also changes its position very rapidly in an east-southeast direction, so that in the north of the Gulf of Bengal it occupies a small part of the southern Himalayas and the whole of Bengal as far as Calcutta. The isobar 754 millimeters (29.70 inches) embraces the

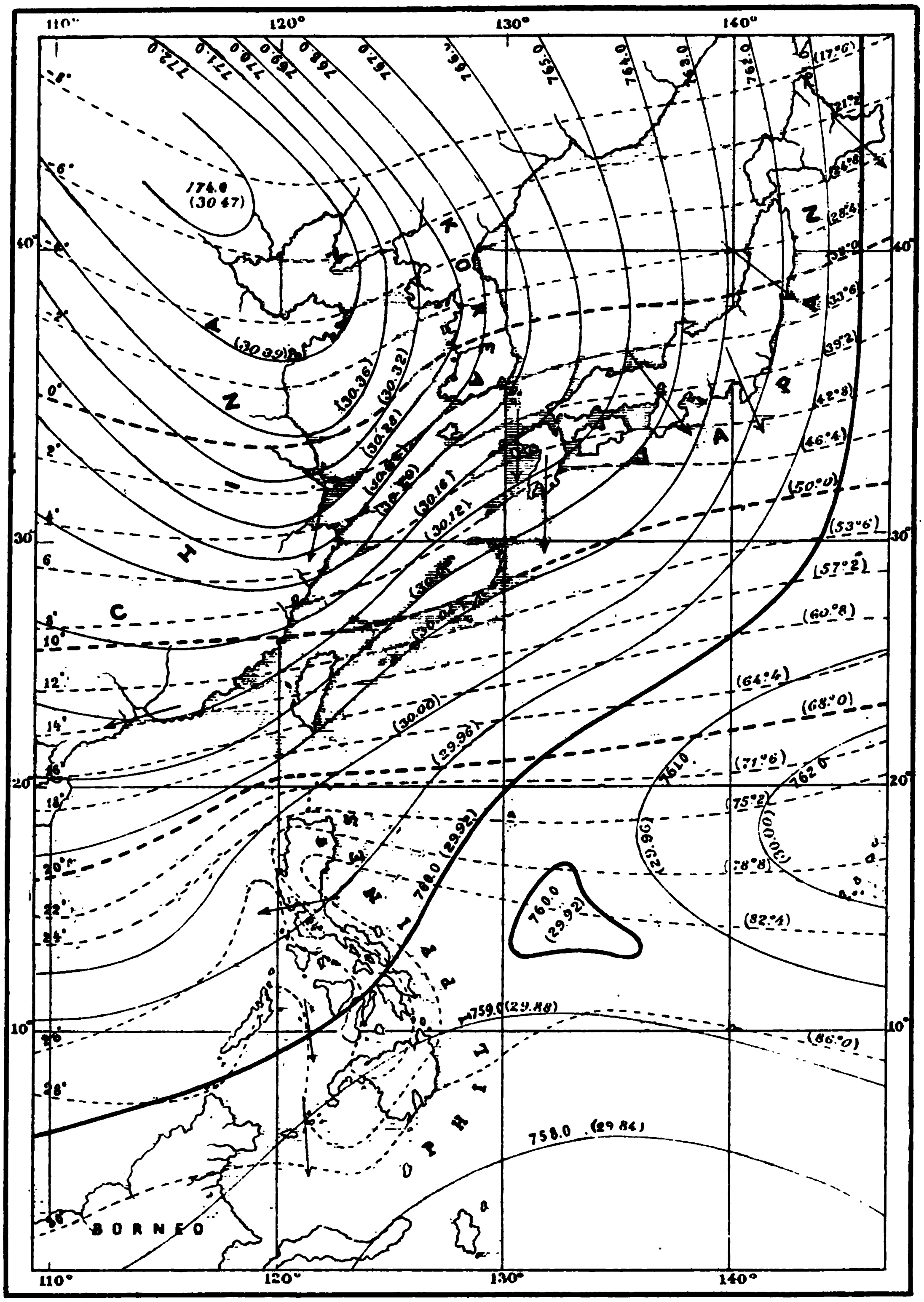
ISOBARS AND ISOTHERMS OF JANUARY

Plate IV.



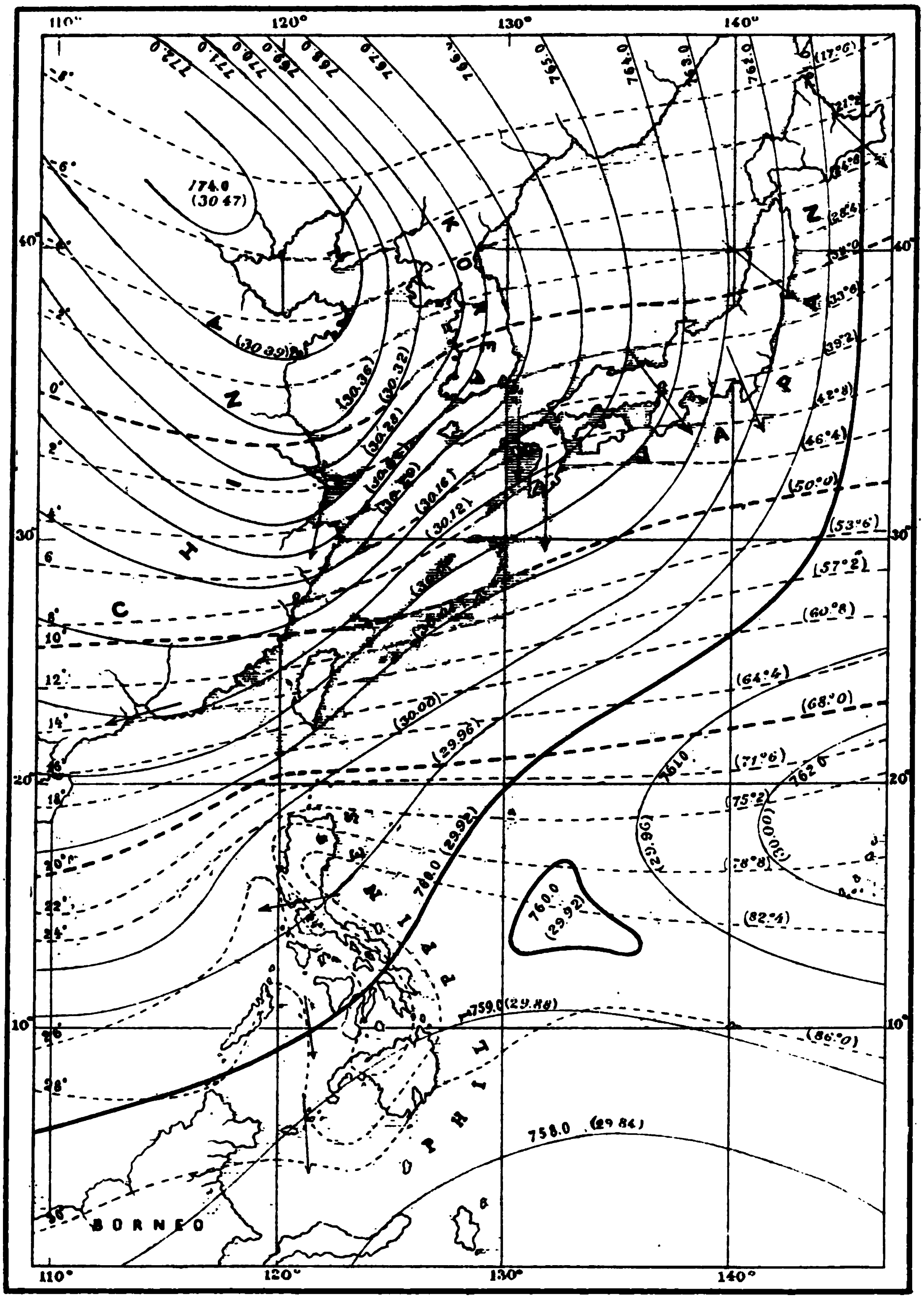
ISOBARS AND ISOTHERMS OF FEBRUARY

Plate V.



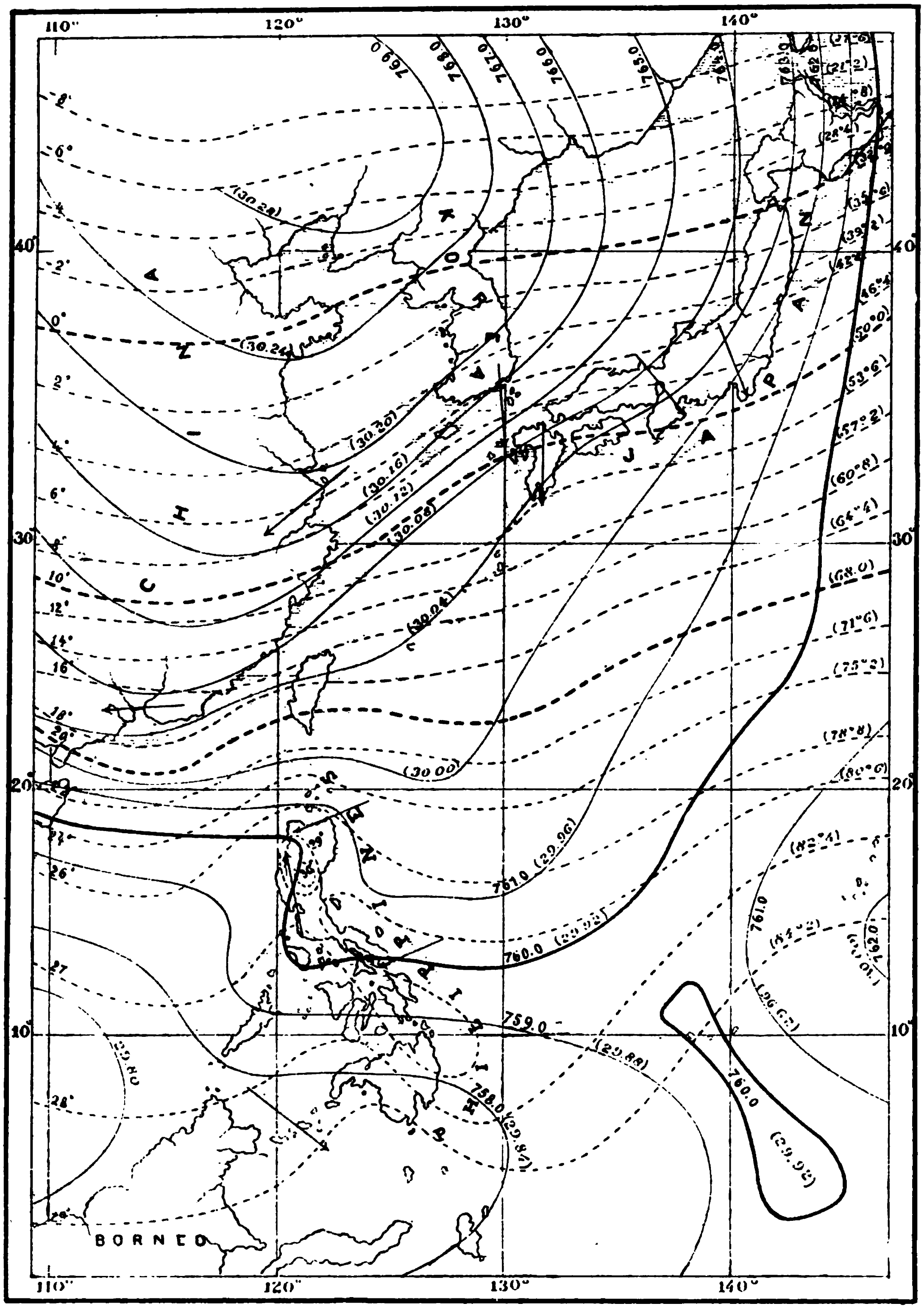
ISOBARS AND ISOTHERMS OF FEBRUARY

Plate V.



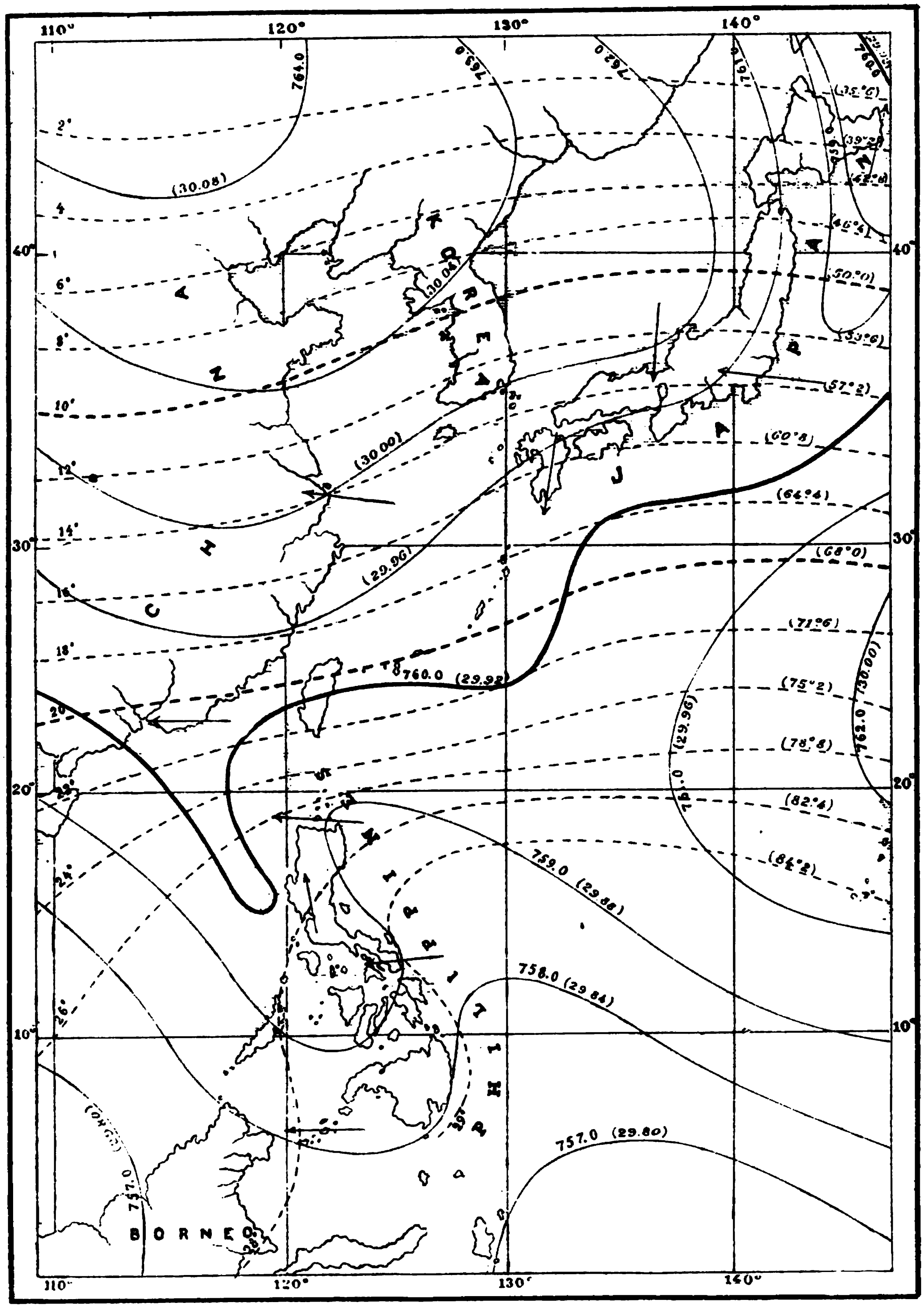
ISOBARS AND ISOTHERMS OF MARCH

Plate VI



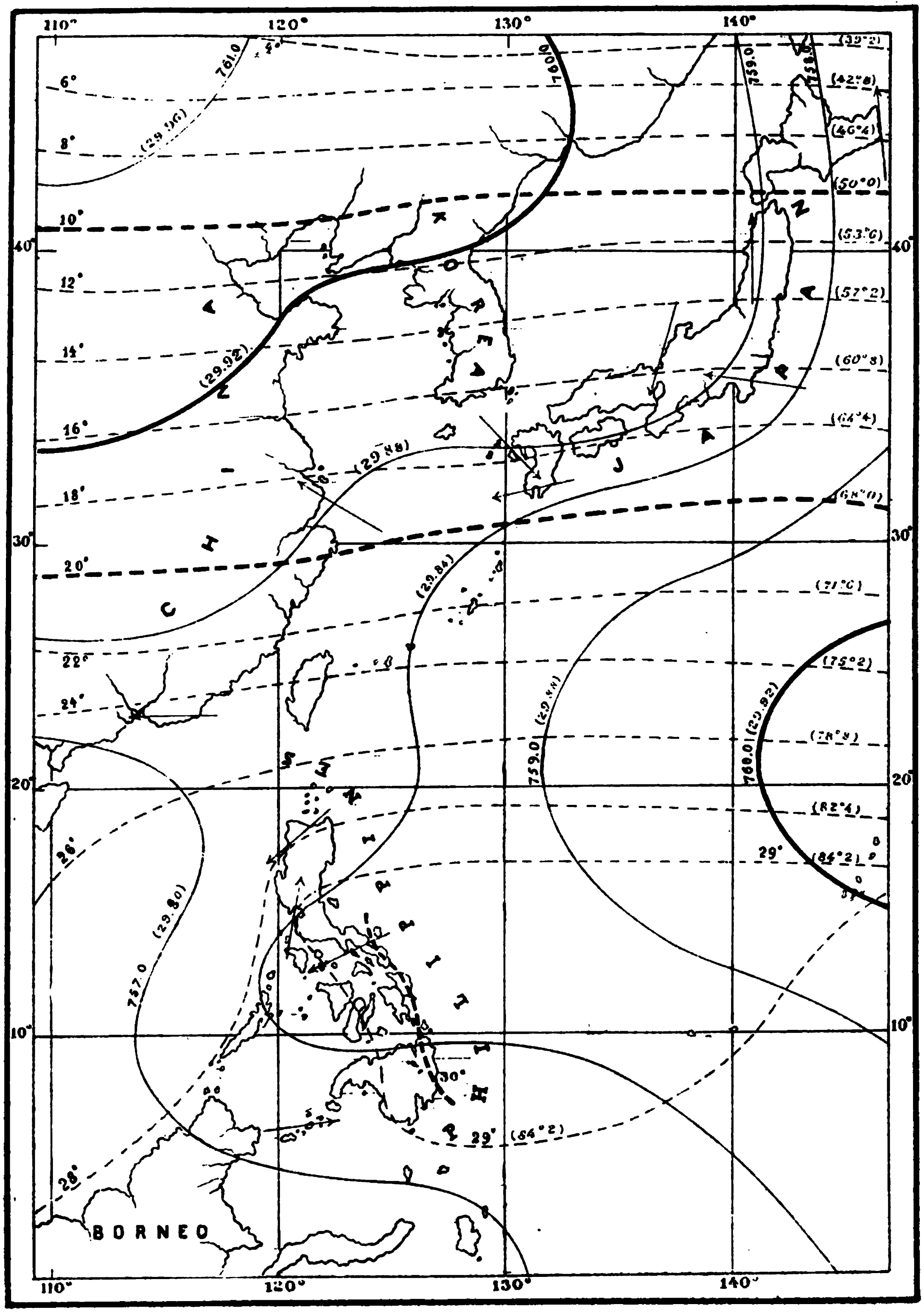
ISOBARS AND ISOTHERMS OF APRIL

Plate VII.



ISOBARS AND ISOTHERMS OF MAY

Plate VIII.



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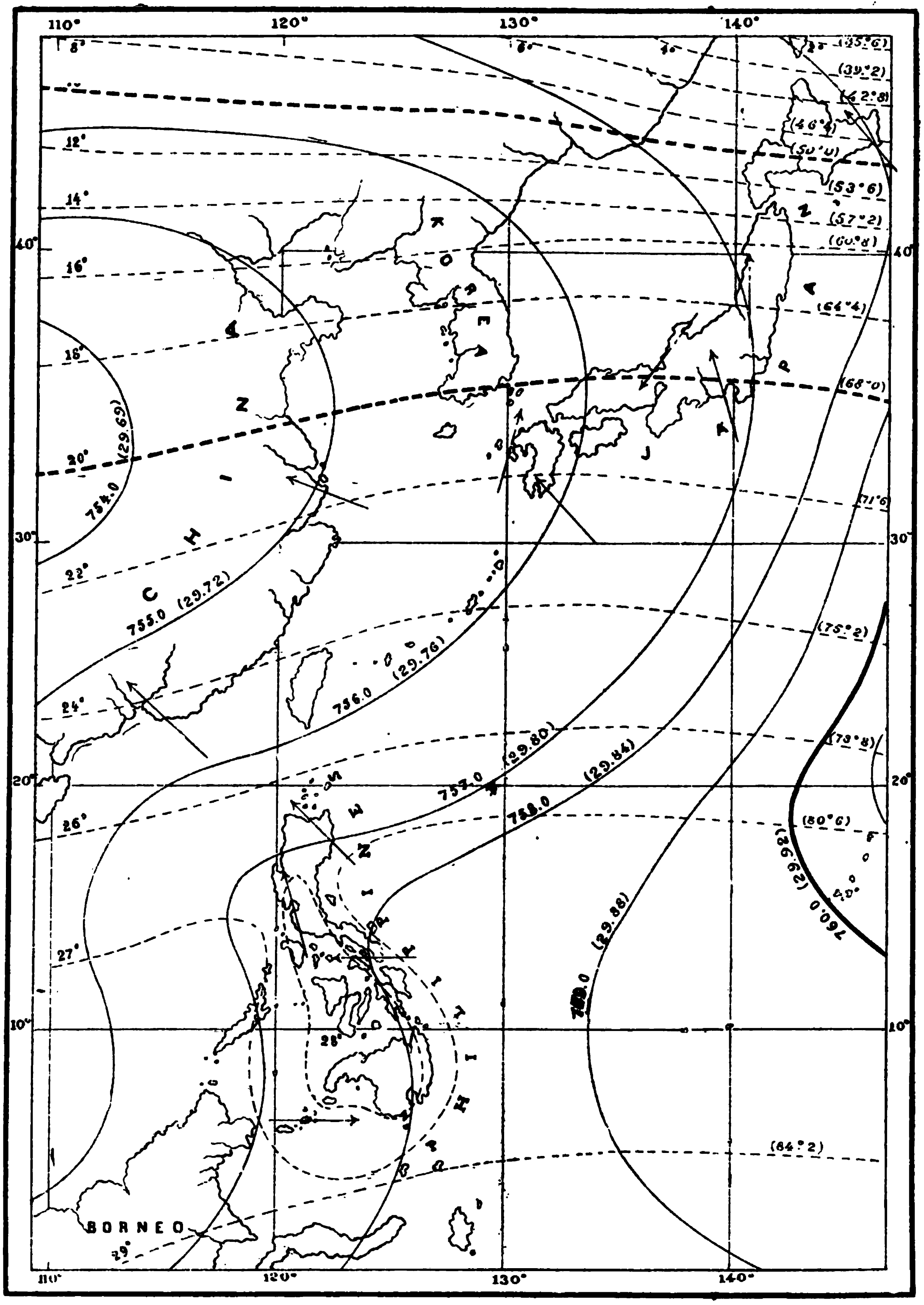
ISOBARS AND ISOTHERMS OF JUNE

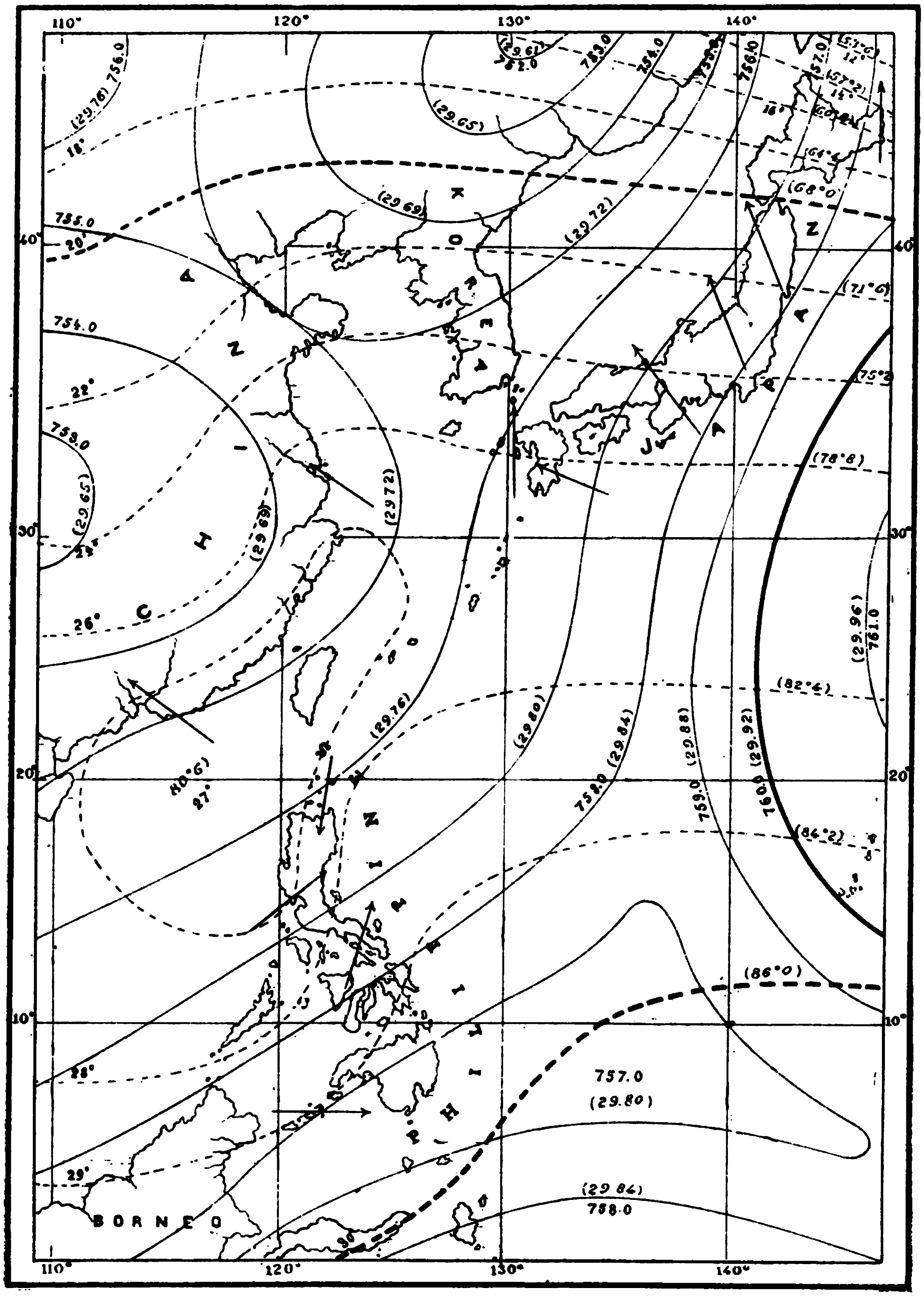
Plate IX.



UNIV. OF MICH.

ISOBARS AND ISOTHERMS OF JULY

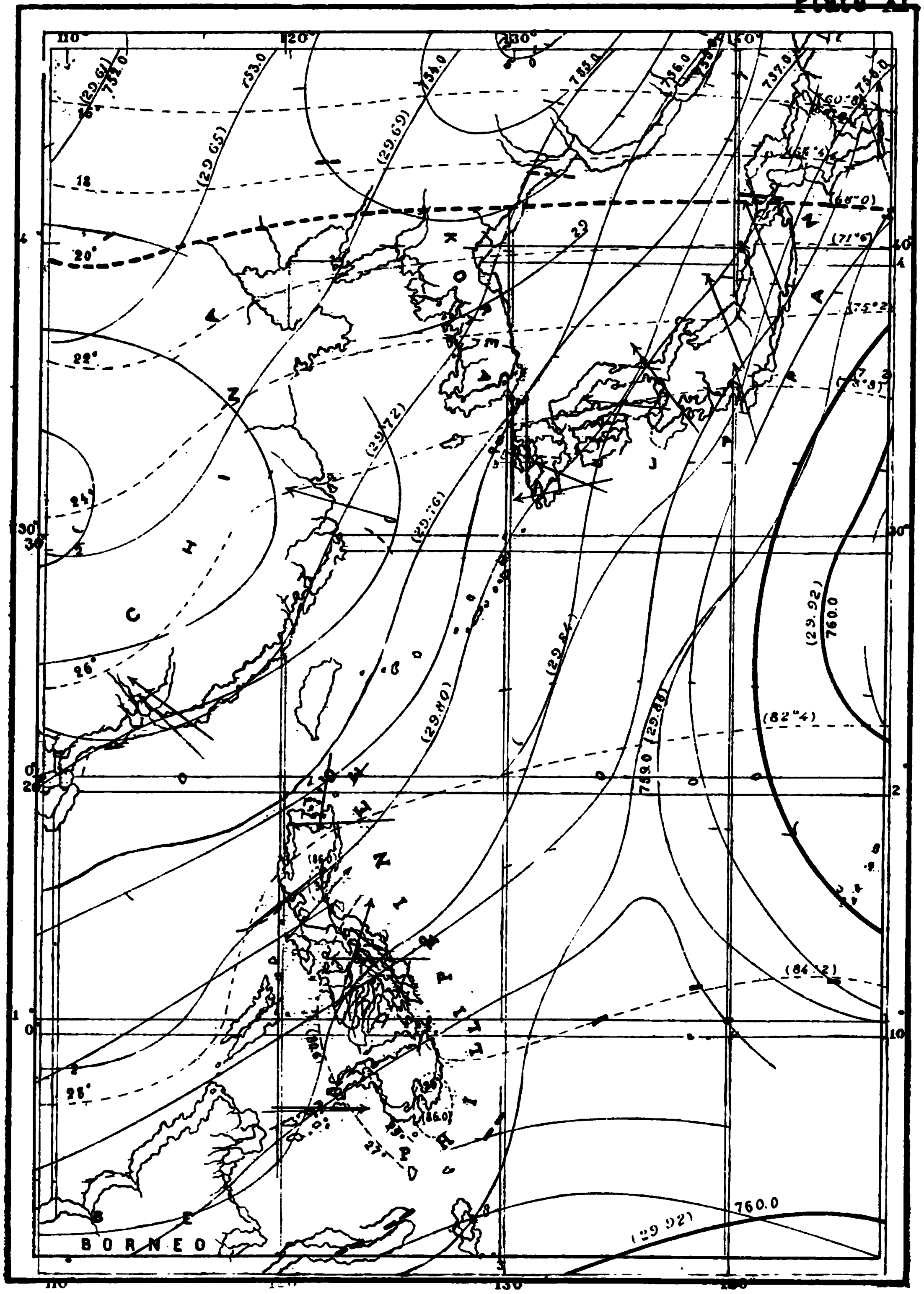
Plate X.



UNIV. OF MICH.

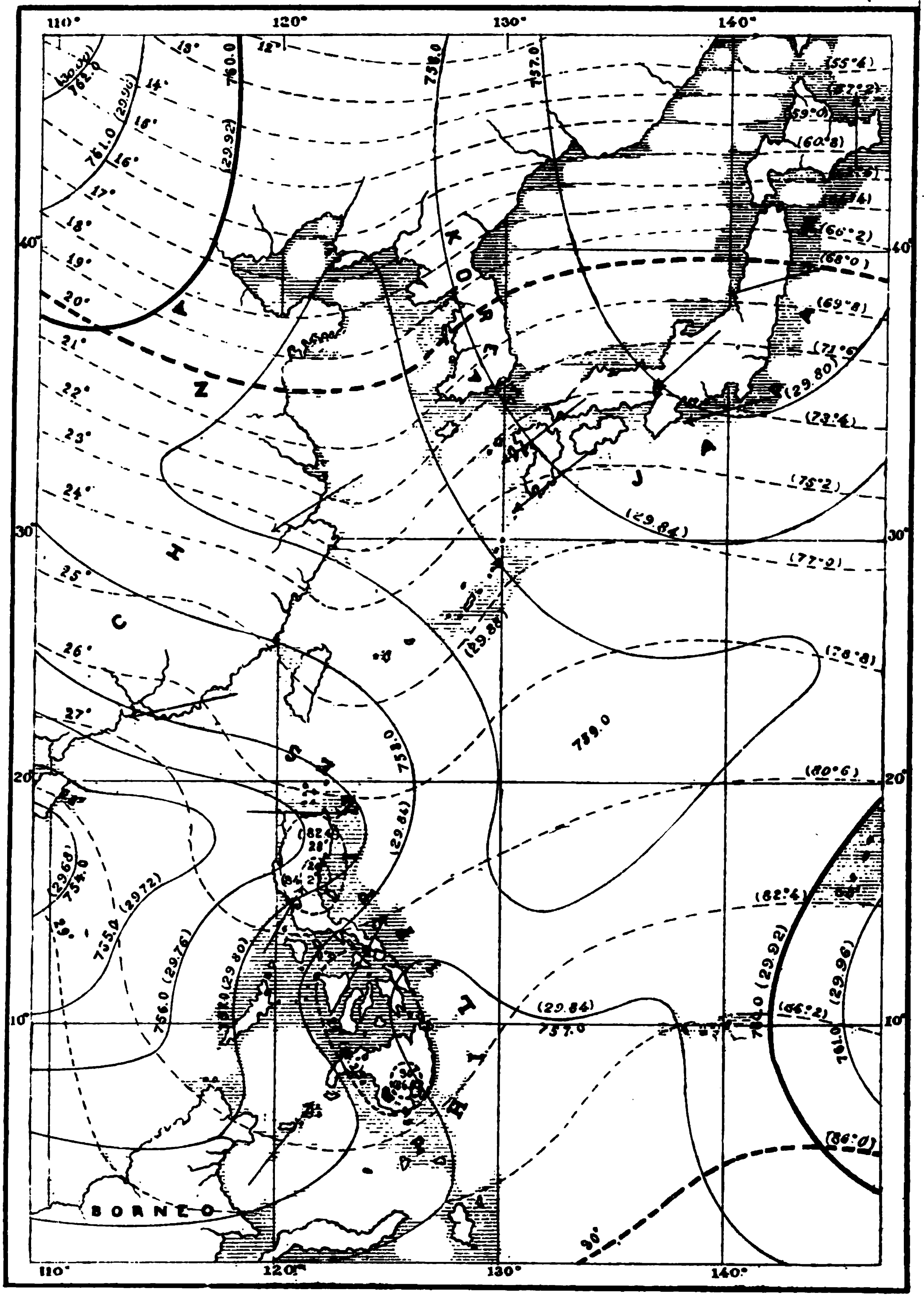
ISOBARS AND ISOTHERMS OF AUGUST

Plate XI



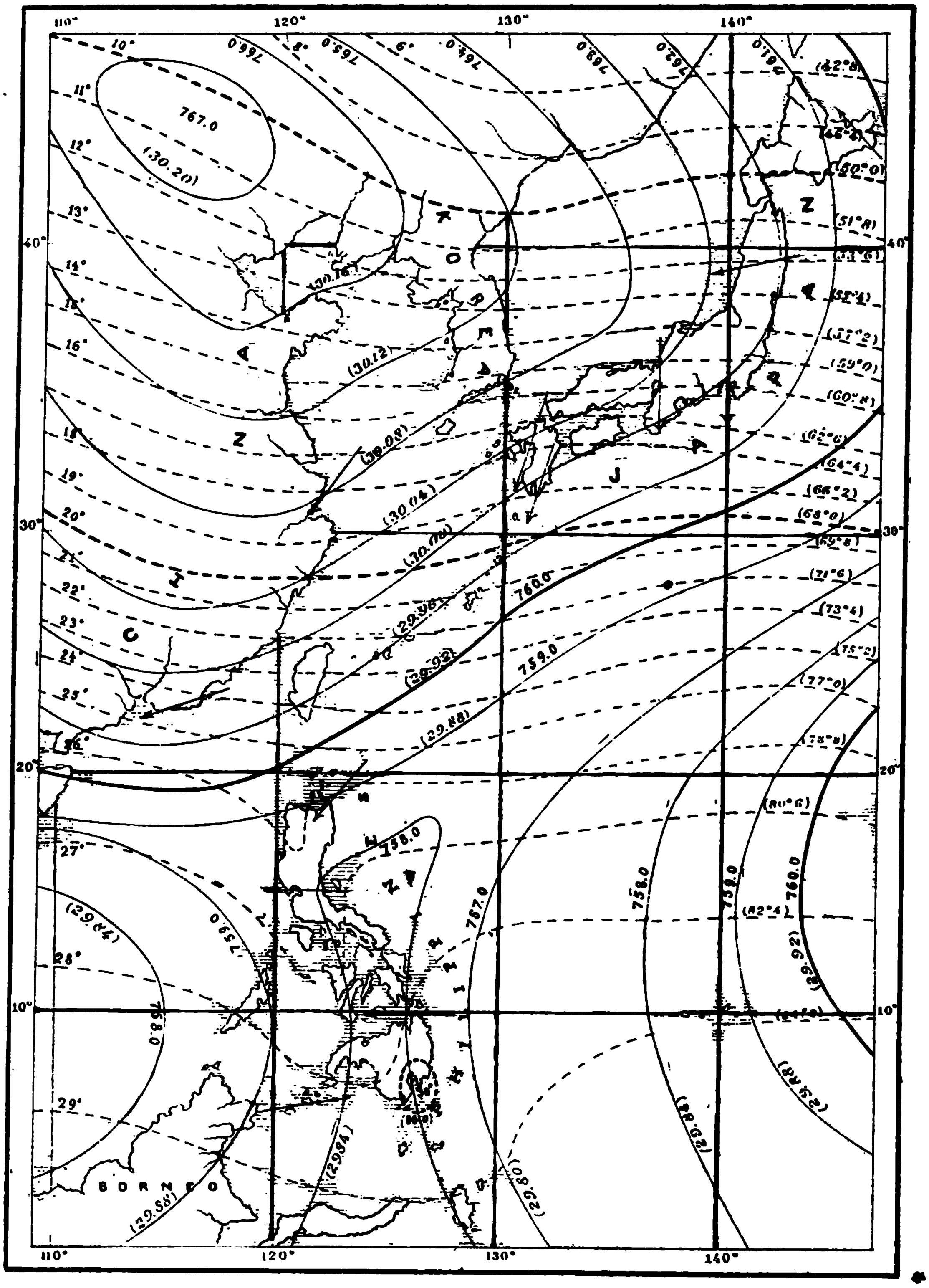
ISOBARS AND ISOTHERMS OF SEPTEMBER

Plate XII.



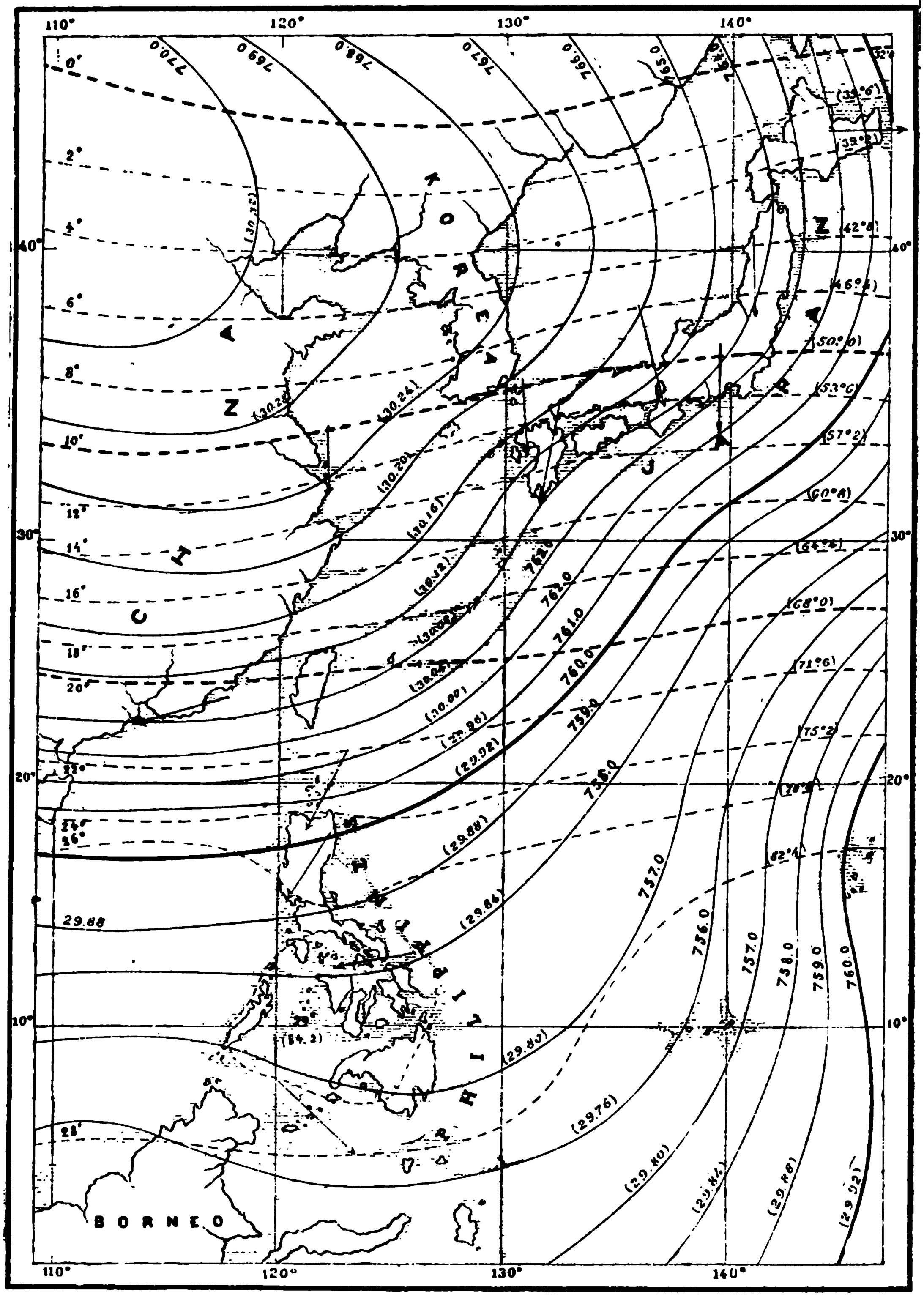
ISOBARS AND ISOTHERMS OF OCTOBER

Plate XIII.



ISOBARS AND ISOTHERMS OF NOVEMBER

Plate XIV.



MICH.

Island of Hainan and the Gulf of Tonkin. At the same time the pressure increases very much in Siberia, but decreases at sea to the north of Japan.

The area of high pressure, which during the previous month was lying in the latitude of southern Japan, has disappeared to the northward, and a new high-pressure area shows itself in the vicinity of the eastern Carolina Islands. (See Pl. XII.)

Hence the center of lowest pressure lies to the west-northwest of Manila, exactly as in May; an area of low pressure extends over the whole Peninsula of Kamschatka and to the northeast of Manila, whilst the area of high pressure lies at a considerable distance to the east of the Archipelago.

In the interior of the Archipelago the conditions of temperature change but little from August to September; in higher latitudes the change is greater, amounting to 1° C. (1.8° F.) for each degree. We find the region of highest temperature in the Archipelago in the interior of Mindanao from Davao as far as south of Taganaan.

The tracks of cyclones of the third group (see Chart).—As a general characteristic of the months constituting the third group it may be stated that from June to September—at least until the second half of the latter month—the center of high pressure disappears from the neighborhood of the eastern coast of Asia, and this fact seems to render easier the passage of cyclones into the continent in higher latitudes. The same circumstance also explains why some of the cyclones of the Pacific recurve as far west as the one hundred and twenty-fourth meridian east of Greenwich.

In general the typhoons of the Pacific Ocean occurring during the months of this third group recurve much nearer to the Philippine Archipelago than those of the preceding months, with the exception of the storms during the second half of September. Some of these latter have the vertex of their trajectories between the one hundred and twenty-ninth and one hundred and thirty-second meridians east, but as to the rest we have not seen a single track which recurved east of the one hundred and twenty-ninth meridian. All these typhoons of the Pacific take their course toward the northern area of depression.

With regard to the cyclones of the China Sea it may suffice to state that, in proportion as the continental center of low pressure recedes toward the north, the northerly inclination of their tracks increases, reaching its maximum at the end of August and the beginning of September. During the second half of September the depression advances again into lower latitudes, and to this movement corresponds a diminution of the northern inclination of the typhoon trajectories, which inclination attains its minimum during the months of the first group.

The fact that some of the cyclones of July recurve along a trajectory which has a strong inclination toward north in order to reach the Yellow Sea finds its explanation in the presence of a very small area of low pressure in Siberia, and this again confirms the statement that *the cyclones turn toward the areas of depression.*

WORKS WHICH MAY BE CONSULTED IN CONNECTION WITH CHAPTER VIII.

BAUDENS. Notice sur les Typhoons des Mers de Chine et du Japon. Ann. Hydrog., No. 659.
CHEVALIER, Rev. P., S. J. Bulletins Mensuels de l'Observatoire de Zi-ka-wei. 1887–1895.
——— Typhoons de 1892. Juillet, Aout, Septembre.
——— The "Bokhara" Typhoon. October, 1892.
——— On the Typhoons of the Year 1893.
DESCHEVRENS, Rev. P., S. J. Bulletins Mensuels de l'Observatoire de Zi-ka-wei. 1874–1886.
——— The Typhoons of the Chinese Seas. 1880.
——— The Typhoons of the Chinese Seas. 1881.
——— Les Typhoons de 1882. Juillet, Aout.
DUPERRÉ. Typhoons dans la Mer de Chine. Ann. Hydrog., No. 640.
FROC, Rev. A., S. J. Typhoon Highways in the Far East. Zi-ka-wei, 1896.
——— The "Iltis" Typhoon. July, 1896.
GARRIOTT, E. B. The Windward Islands Hurricane. Monthly Weather Review, September, 1898, p. 391.
——— The West India Hurricane. Monthly Weather Review, October, 1898, p. 439.
JORNIER. Typhoons dans la Mer de Chine et du Japon. Ann. Hydrog. (From the Russian.)

CHAPTER IX. FREQUENCY OF CYCLONES.

NUMBER OF CYCLONES OBSERVED IN THE PERIOD OF 1880 TO 1901 AND THEIR DISTRIBUTION THROUGHOUT THE DIFFERENT MONTHS OF THE YEAR.

In the first place, we believe it will be of especial interest and practical value to know something of the distribution of cyclones over the different months of the year, so as to find in what month they appear with greatest frequency and what months are free from them. For this purpose we have included those cyclones which have appeared in this Archipelago, either crossing it or passing through it for a greater or less distance, and whose trajectory this observatory has been able to discover. There are 468 of these cyclones, whose distribution by month and year can be seen from the following table:[1]

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1880							2	4	2	2	1		11
1881					2	1	3	4	4	3	3	1	21
1882				1			3		2	2	1	2	11
1883			1	1	3	1	3	4	4	4	1		22
1884	1				2	1	4	5	4		2	2	21
1885				1		2	2	2	1	1	1	1	11
1886				1	1	2		3	4	3	1	1	16
1887			1	3	3	1	5	2	7	3	3		28
1888				1		2	4	3	3	1	1	1	16
1889							2	3	2	4	1	2	14
1890	1				1	5	4	2	7	6	1		27
1891				1	2	2	7	5	6		4	1	28
1892	1					3	4	4	5	2	3	2	24
1893	2				2	1	3	4	6	3	2	1	24
1894					4	3	5	3	5	5	6	3	34
1895	1				1	4	2	3	5	3	5		24
1896					1	2	4	4	5	4			20
1897						2	6	2	3	5	2		20
1898			1		2	3	3	6	4	3	2	1	25
1899				1	1	1	4	3	4	2	4	1	21
1900	1					3	1	5	3	3	4	3	23
1901	2	2	2			2	3	3	2	6	3	2	27
Total	9	2	5	10	25	41	74	74	88	65	51	24	468
Mean	0.4	0.1	0.2	0.5	1.1	1.9	3.4	3.4	4.0	2.9	2.3	1.1	21.3

As will be seen, not one of the 441 cyclones which have been registered from 1880 to 1900, inclusive, has been observed in the month of February and only 5 in the month of March from 1880 to 1901. Their frequency then increases from April, when 10 occurred, to July, when 74 were observed. The maximum of 88 is reached in September, thus giving a yearly average of 4 for this month. From October the number gradually diminishes up to January, for which month but 9 are recorded.

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[1] We begin with the year 1880, as this was the first year in which our Observatory sent notices of typhoons to the neighboring colony of Hongkong. Telegraphic communication was then established.

ANNUAL AVERAGE FOR THE PERIOD 1880 TO 1902.

Taking the average of the total number of cyclones observed during the twenty-two years included in the previous table we find a general yearly average of 21.3. This average would be greater if we should include only the last ten years as, on account of more available data and better methods of observations, it has been difficult for any typhoon to occur in these seas without being recorded. This was not true of the first few years, because methods of securing information were much more defective. In confirmation of this it is sufficient to say that since 1892, when this Observatory began to receive monthly reports of the daily observations taken on the Island of Guam (Marianas Islands), we have been able to record various cyclones, as, for example, three for the month of November, 1895,[1] and one for the month of April, 1899,[2] which passed near that island on the south and west in the Pacific without coming near the Philippines and concerning which we would have had no information if it had not been for these reports. (See Pl. XVI.)

Again, in the same meteorological review of the Monthly Bulletin of this Observatory for the years 1880, 1881, and 1882 we find various phenomena described for which we could not then give a satisfactory explanation, but which we now know take place whenever a cyclone occurs at some distance from the Archipelago, especially in the vast extent of the Pacific Ocean east and northeast of Luzon. Such are, for example, the winds from the southwest, which blow during certain days in the months of April and May and which are accompanied with frequent showers and squalls. This happened among other cases which we might cite, during the last ten days of April, 1880, and May, 1882, during which months no cyclone was recorded, not because they did not occur, but because at that time we did not have the same facilities as at present for studying and tracing their paths.

ANNUAL MEAN FOR THE LAST TWELVE YEARS.

In view of this, taking the cyclones registered during the last twelve years—that is to say, from 1890 to 1901, inclusive—we find an average of 24.6 cyclones for each year, while the general mean is only 21.3 per year.

DIVISION OF THE CYCLONES OBSERVED DURING THE PERIOD 1880–1901 INTO FOUR GROUPS ACCORDING TO THEIR MINIMUM DISTANCE FROM MANILA.

Taking as a foundation the 397 cyclones registered only during the years 1880 to 1898 we shall consider in this paragraph their relative distance with regard to Manila. This we believe will be of as much importance and interest as what has been said in the foregoing paragraphs. For this purpose we have divided these cyclones into four groups according to their minimum distance from the capital of the Archipelago, as follows: First group, less than 10 miles; second, from 10 to 60 miles; third, from 60 to 120 miles; fourth, more than 120 miles.

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[1] We give a short account of these cyclones in the meteorological review in our Monthly Bulletin for November, 1895. The last of these, which occurred in the Marianas the 20th, touched the southern part of the port of San Luis de Apra where the barometer fell 22 millimeters in two hours and ten minutes, the lowest reading being 730.6 millimeters. The wind blew a hurricane from north-northwest and north to northeast and southeast, causing much damage in the town. The veering of the wind from northeast to southeast took place after half an hour of relative calm.

[2] This cyclone was felt in Guam on the 25th and the 26th. For the observations concerning it we are indebted to the generosity of Mr. Stovell, captain of the steamer *Nansham* which was anchored there at the time. According to these observations the barometer reached its lowest reading of 741 millimeters at 4 p. m. of the 25th, and the winds, having a velocity of 8, 9, and 10, according to the Beauford scale, were successively from east to southeast, south. and southwest, and were accompanied with strong squalls. The storm moved around the west of Guam without touching the Philippine Archipelago. The movement of this cyclone about the Island of Guam is indicated not only by what we have just said concerning the change of winds, but also by the maintenance of the barometric pressure during the whole of the 26th at about the same height that it was in the afternoon of the 25th. Nevertheless the observations of the 26th and the 27th would seem to indicate that it again turned to the north or north-northwest, from which point it was not possible to follow its farther course in the Pacific.

Distance (minimum).	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Miles.													
0 to 10	------	------	------	------	1	------	------	------	1	1	3	------	6
10 to 60	------	------	------	------	6	1	2	2	7	6	3	1	28
10 to 120	------	------	1	1	2	3	4	4	5	9	3	4	36
Over 120	5	------	2	8	15	31	60	57	66	39	31	13	327

MONTHS IN WHICH OCCUR THOSE CYCLONES MOST TERRIBLE AND DANGEROUS FOR MANILA.

From these data it is evident that the months when the cyclones are most likely to become dangerous to Manila are May, September, October, and November; for in those months there have been registered the six cyclones which during the period 1880–1901 crossed the island and passed within 10 miles of the capital. Besides, of the 28 cyclones which passed within a distance of from 10 to 60 miles of Manila 22 occurred during the four months mentioned. In July and August, even when cyclones are inclined toward the west, they usually pass along the higher latitudes and are more dangerous to the north of Luzon, Formosa, and the coast of China lying between Hongkong and Shanghai. Nevertheless, as rare cases we should mention certain cyclones which crossed the Archipelago through the Visayan Islands or south of Luzon even in these months. Such was the cyclone which on August 1 and 2, 1896, crossed the southern part of Luzon and whose course is given in Chapter X of this part (see Pl. XXIV, No. 5); also that of the 3d and 4th of August, 1897, which crossed the Islands of Luzon and Panay.[1]

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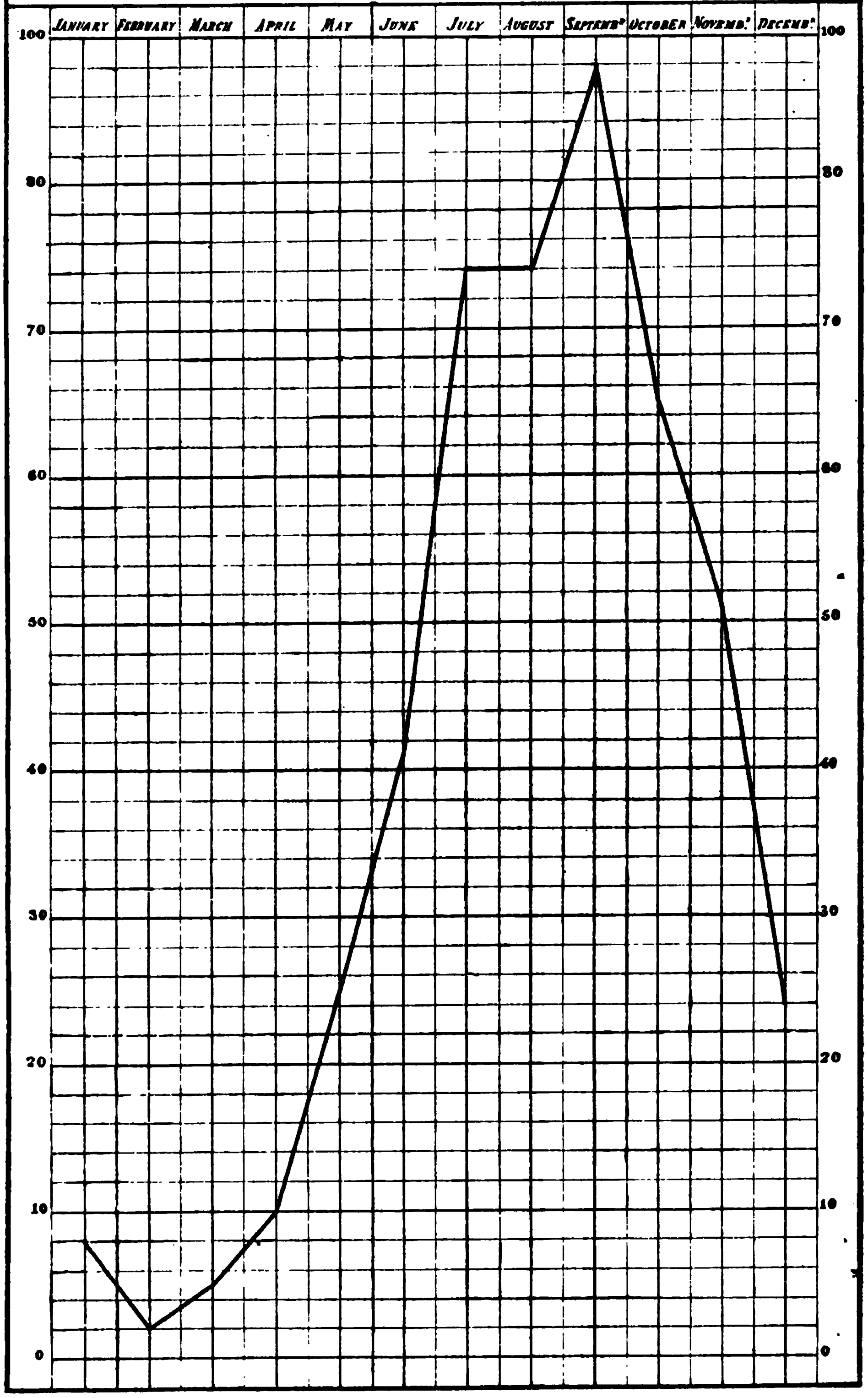
[1] **The first of these cyclones is described at length in the work entitled "Tifones del Archipiélago Filipino y mares circunvecinos 1895 y 1896," by Rev. John Doyle, subdirector of the Observatory. The second is described briefly in the meteorological review of our Monthly Bulletin for August, 1897.**

Plate XVI.

MONTHLY DISTRIBUTION OF THE BAGUIOS OR CYCLONES IN THE FAR EAST

1880-1901



CHAPTER X. THE CLASSIFICATION OF CYCLONES.

The elements of classification.—The first method of classification could be to group the typhoons according to the time of their formation, and accordingly we should have to draw a distinction between the cyclones of May, June, July, etc. This division would be suitable if there were a question of a classification of cyclones according to the form and the inclination of their tracks, for the seasons of the year are the first cause of the variability of these tracks. Another classification might be based upon the regions towards which cyclones take their course, and thirdly, they might also be classified according to the regions over which they usually travel. The last named classification is, we believe, that which gives rise to the fewest mistakes.

Classification.—The division into cyclones of the Pacific Ocean and of the China Sea which repeatedly has been employed in the preceding chapters corresponds to the third mentioned classification, and this we believe to be the most suitable. The Hydrographic Office in Washington in its classification adopts that proposed by Father Chevalier, namely: Into typhoons (1) of China; (2) of Cochin China; and (3) of Japan. This division is according to our view insufficient, inasmuch as there are cyclones which make themselves felt in the Archipelago, recurve to the eastward of Luzon, and travel along the second branch of their parobolic track far to the south of Japan without exercising any, or at least but a very small, influence on that country. None of the above groups comprises these typhoons because they are felt neither in China nor in Cochin China nor in Japan. Hence we can not say that these typhoons belong to any of these divisions, and the same is true of a good many tracks in January, February, March, April, and May, October, November, and December. But there are even cyclones which run into the China Sea, recurve there (scil. west of Luzon), and traverse the Pacific again on the second branch of their track. They neither reach the Asiatic continent nor are they felt in Japan, but these cyclones have also to be considered in a classification of such phenomena. Examples of this class are the well known typhoons of May 8 to 14, 1895, in which the steamship *Gravina* was lost and with her hundreds of lives; and also the cyclone of May 10 to 19, 1896, the center of which passed over Iloilo. (See Pl. XXVI, Nos. 3 and 4.)

The Hydrographic Office of Washington comes, therefore, with Fr. Chevalier to a conclusion which in our opinion is erroneous—that is, that the typhoons of the Philippines must either belong to the China Sea or Cochin China class of typhoons. The two instances mentioned should suffice to prove the error of this supposition.

The subdivisions of cyclones.—We may conveniently divide the cyclones of the Pacific into cyclones of Japan and cyclones of the Magallanes. The former originate in the Pacific and recurve before reaching the one hundred and twenty-fourth meridian east of Greenwich in order thence to travel over the Islands of Japan; the latter take their rise in the Pacific, recurve, and generally cross the region of the Magallanes Archipelago.

The first-named cyclones develop during June, July, August, September, October, and November and the others during the months of the first and second group.

The typhoons of the China Sea we divide into the typhoons of Mindanao, Visayas, and Luzon. The cyclones of Mindanao pass over this island during the months of the first group. The cyclones of the Visayas are those which cross the central Philippines in a northwesterly direction and generally occur during the months of the second group, but especially in April and May, sometimes also in December. The typhoons of Luzon pass over this island in a northwesterly direction, or else they pass in nearly the same direction very close to the north of that island. They belong to the third group, but appear also in October and November.

The cyclones of Mindanao belong to those of Cochin China according to Fr. Chevalier's division. Of those of the Visayas some fall under the group of Cochin China, others of that of China, but some belong to neither class, but are exclusively Philippine typhoons, as, for instance, the "Gravina" typhoon (1895), the cyclone of Iloilo (1896), and others. The cyclones of Luzon are really China typhoons, but to these belong also those cyclones of Japan which are not Pacific typhoons and also those which recurve in the Formosa Channel and travel toward Japan; furthermore, those which have reached the China coast then recurved to the northeast—generally speaking, all cyclones which have crossed the one hundred and twenty-fourth meridian east of Greenwich and again recurve toward Japan or the Japan Sea.

The very rare typhoons which originate in the China Sea may be counted as belonging to one of the three classes above enumerated according to the latitude in which they are formed. They are formed north of 10° north; some of them not only originate but also run their course and end within the China Sea, and these we designate as being typhoons which belong exclusively to the China Sea.

Division according to the course of the track.—All cyclone which develop in the Far East and disappear there can be divided as follows:

1. Cyclones of the Pacific
    - Cyclones of Japan.
    - Cyclones of Magallanes.
2. Cyclones belonging exclusively to the China Sea.
3. Cyclones of the China Sea
    - Cyclones of Mindanao
        - Cyclones of Annam.
        - Cyclones of Cochin China.
    - Cyclones of the Visayas
        - Cyclones of Cochin China.
        - Cyclones of Tonkin.
    - Cyclones of Luzon
        - Cyclones of China.
        - Cyclones of Japan.
4. Cyclones of the Philippines, strictly speaking.

The last enumerated cyclones are the typhoons of the Visayas or of Luzon, which do not reach the Asiatic continent or recurve in the China Sea in order to reach the Archipelago again, or else those which recurve in the interior of the Archipelago itself. We call these "cyclones of the Philippines, strictly speaking," so as to be able to distinguish them from those previously enumerated. All classes might be called typhoons of the Philippines in a general sense, because they all make themselves more or less felt in the Archipelago.

CLASSIFICATION OF THE CYCLONES OF THE FAR EAST BY ZONES OF FORMATION AND COURSE OF TRAJECTORY.[1]

1. Cyclones formed in the Pacific
    - Cyclones of Marianas or Magallanes.
    - Cyclones of Japan
        - Cyclones which pass at a great distance from the meridian of Manila.
        - Cyclones which pass near the meridian of Manila after or before traversing it.
    - Cyclones of Formosa.
    - Cyclones of the Philippines
        - Cyclones of Luzon
            - Cyclones which cross north of Manila
                - Cyclones which recurve in the interior of Luzon or not far from the island in the China Sea. Cyclones of China, Tonkin, Cochin China.
            - Cyclones which cross south of Manila.
        - Cyclones of the Visayas and of Mindanao.
        - Cyclones which are formed in the Pacific between the tenth and twentieth parallels north, crossing first by the south and then by the north of Manila.
2. Cyclones formed in the China Sea.
3. Cyclones formed in the Sea of Jolo or interinsular seas of the south of Luzon.

Of the cyclones considered in the principal table of the foregoing chapter, 82 per cent belong to the first principal member of this division, 15 per cent to the second, and only 4 per cent to the third.

Of the typhoons of the Visayas and Mindanao, of those formed in the China Sea and in the seas of the south of Luzon, some disappear in the China Sea before reaching the continent and others, the majority, penetrate into it by the south of China to Tonkin or Cochin China. Those formed in the China Sea are very seldom directed toward Formosa or to Japan. Not so those of the Visayas and Mindanao which in such case pertain to the last of the three groups of baguios which we have named baguios of the Philippines because they traverse these islands.

As regards the subdivisions we have made of the typhoons formed in the Pacific we have only to observe: 1. That those which we call cyclones of the Marianas or Magallanes are those which spend themselves in the same ocean in which they were formed without reaching our Archipelago or which recurve in such a manner that in the second branch of their parabolic trajectory they do not turn toward Japan nor pass close by that country, but wind about in the Magallanic Archipelago. 2. That by cyclones of Japan we understand not only those which actually traverse Japan, but also those which after recurving pass through the seas of Japan or in the neighborhood of that empire. 3. That by cyclones of Formosa, of Luzon, of the Visayas, and of Mindanao we understand all those which traverse the said islands or at least cross *not very far from them,* some in the direction of the east coast of China and others in that of the China Sea, whether or not they reach the Continent.

Paths of the cyclones of the Far East, reduced to eleven principal types—Graphic representation of the veering and intensity of the winds which are to be expected in Manila with cyclones of each one of these types.[2]—The eleven accompanying charts are made in accordance with this classification, and in them the trajectory of the cyclones of the Far East may be seen reduced to eleven principal types. In each one of these charts we have graphically represented by means of arrows the relative intensity and veering of those winds which may be expected in Manila whenever a typhoon of that particular type occurs. The Roman numerals I, II, III, placed by the side of each arrow, indicate the order of sequence of those winds, or the way in which they should veer from the beginning to the end of the supposed trajectory. The other Roman figures refer to the meteorological districts. The number of barbs on each arrow indicates the relative intensity of the winds; that is to say, which winds usually acquire greatest force with the trajectory of the type under consideration. We represent only the relative intensity, because the absolute intensity of these winds depends upon many causes. In our opinion the four principal causes are: The minimum distance at which the vortex crosses, the greater or less development of the typhoon, the bearing of the track, and the inclination of the axis of the storm to one side or other of the trajectory. Of type 6 we exhibit two charts (Pls. XXII and XXIII) with the object of giving a greater number of trajectories of cyclones which during the last two years have crossed the Island of Luzon to the north of Manila.

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[1] Formed from Chapter VIII of the "Climatology of the Philippine Archipelago."

[2] Taken from the work prepared at the Manila Observatory, "El Archipiélago Filipino," Vol. II, p. 206. Government Printing Office, Washington, D. C., 1900.

The trajectories of those typhoons given on Plate XXVI may be subdivided into two classes, namely, those which pass nearest to Manila in the first part of their parabolic path, that is to say, when they cross to the south; and those which, on the contrary, pass nearest to Manila when they cross our meridian on the north, after having recurved in the China Sea. The veering of the winds, which may be expected in Manila with each of these classes of typhoons, is much clearer in the second than in the first. It may happen that the veering of the wind will not be greater than toward the south or south-southwest, especially if the typhoons run far into the China Sea before recurving. But the difference is even more notable in the relative intensity of winds. Those in the first case naturally acquire greater force if from the east, east-southeast, and southeast, being very weak and light if from the third quadrant. On the other hand, when the typhoon passes nearer when it crosses to the north, the winds are strongest when from the southwest and west-southwest, while those from the second quadrant are light or brisk in character. With the object of making this latter difference prominent in Plate XXIV we have distinguished certain trajectories from others by the letters A and B, placed in the vertex of the parabola, and give in two distinct diagrams, marked likewise A and B, the different relative intensities of those winds which correspond to the two classes of trajectories.

We will conclude this paragraph by stating that we have been very careful to select trajectories of the last few years, especially of the period 1895 to 1901, and that in general we have taken them from those months in which baguios of each one of these types are most frequent.

The classification of cyclones according to the velocity of their progressive movement.—Cyclones may be divided according to the velocity of their progressive movement into rapid, regularly progressive, slow, and stationary. This classification, however, is not a general or absolute one, but relative and particular for each region, because the same cyclone may move slowly whilst forming or while remaining in lower latitudes so as to move onward regularly till it recurves, then stand almost still while recurving, and finally travel with great velocity as soon as it reaches higher latitudes. A typhoon is said to travel rapidly in the Philippines if its velocity exceeds 12 nautical miles an hour; it moves with a regular velocity when traveling from 6 to 12 miles an hour; its progress is slow if its onward movement amounts to less than this rate. Of typhoons which have been studied up to date 180 have crossed the Archipelago or the adjoining regions of the ocean with regular velocity, 40 with rapid, and 30 with small speed, while a few remained stationary for several days.

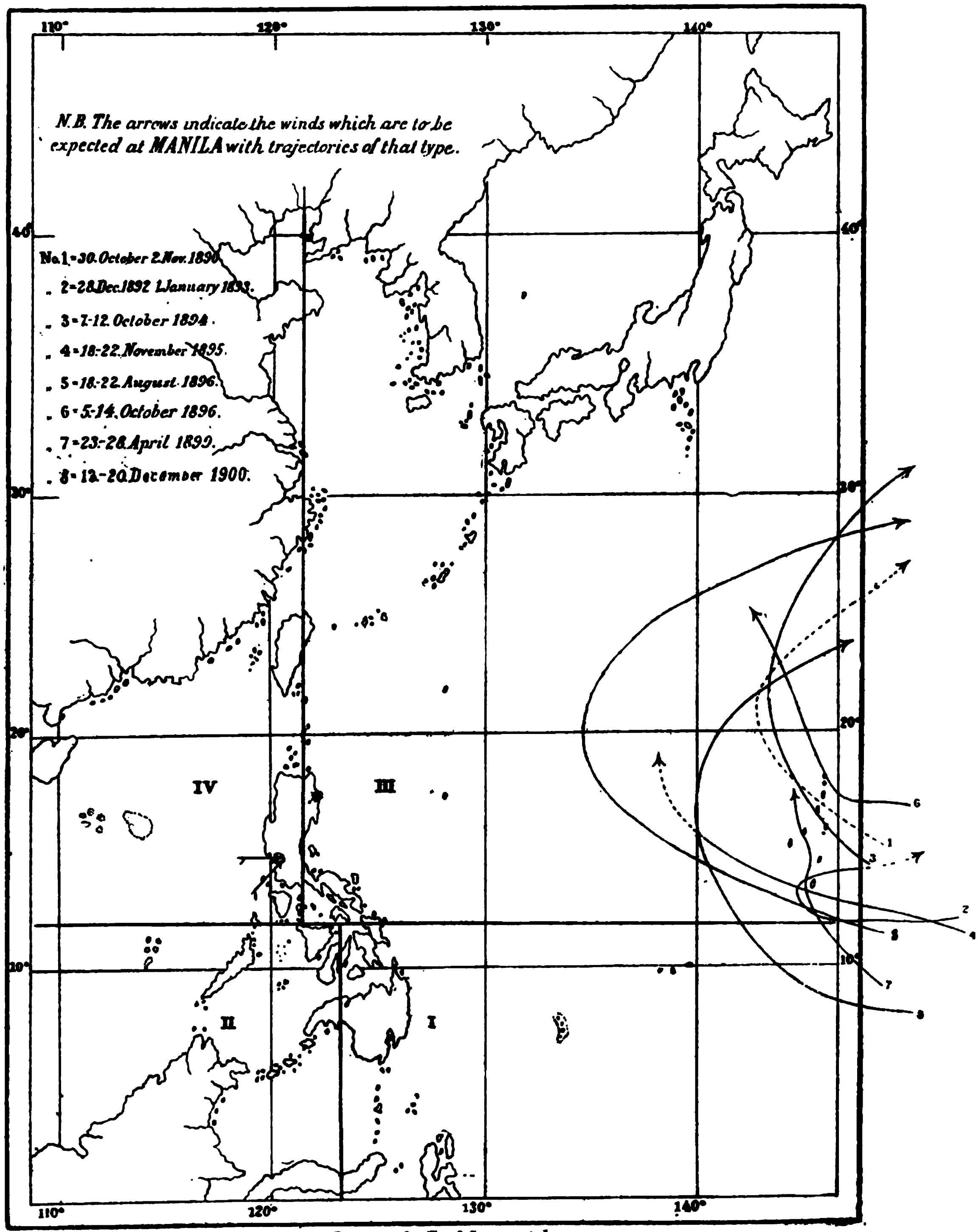
For the convenience of the reader we exhibit on Plate XXIX the mean trajectories of the different types of cyclones. The same may also serve as a kind of compendium of the larger map of typhoon tracks accompanying this work. The weight of each curve depends, of course, on the number of cases from which it has been derived; every track recorded on the respective charts having been taken into consideration except track 7 of type 11, which is completely abnormal. Types 3 and 5 are each represented by two curves. We also added the mean path followed by those atmospheric depressions which, without developing a nucleus, traverse the lower latitudes of the Archipelago during the months of the first and second group. The following are the months during which the cyclones of the various types occur most frequently:

Type 1. During the months of Groups I and II, especially in December and January.
2. During the months of Group III almost exclusively.
3 *a*, 3 *b*. From June until the end of November.
4. Almost without exception during September.
5 *a*, 5 *b*. During the months of Group II.
6. From July to October.
7. During the months of Group II.
8. During the months of Groups I and II.
9. During the months of Group II.
10. During the months of Group III.
11. From July to November.

TYPE 1ˢᵀ

Plate XVII.

CYCLONES IN THE MARIANAS OR MAGALLANE ISLANDS.

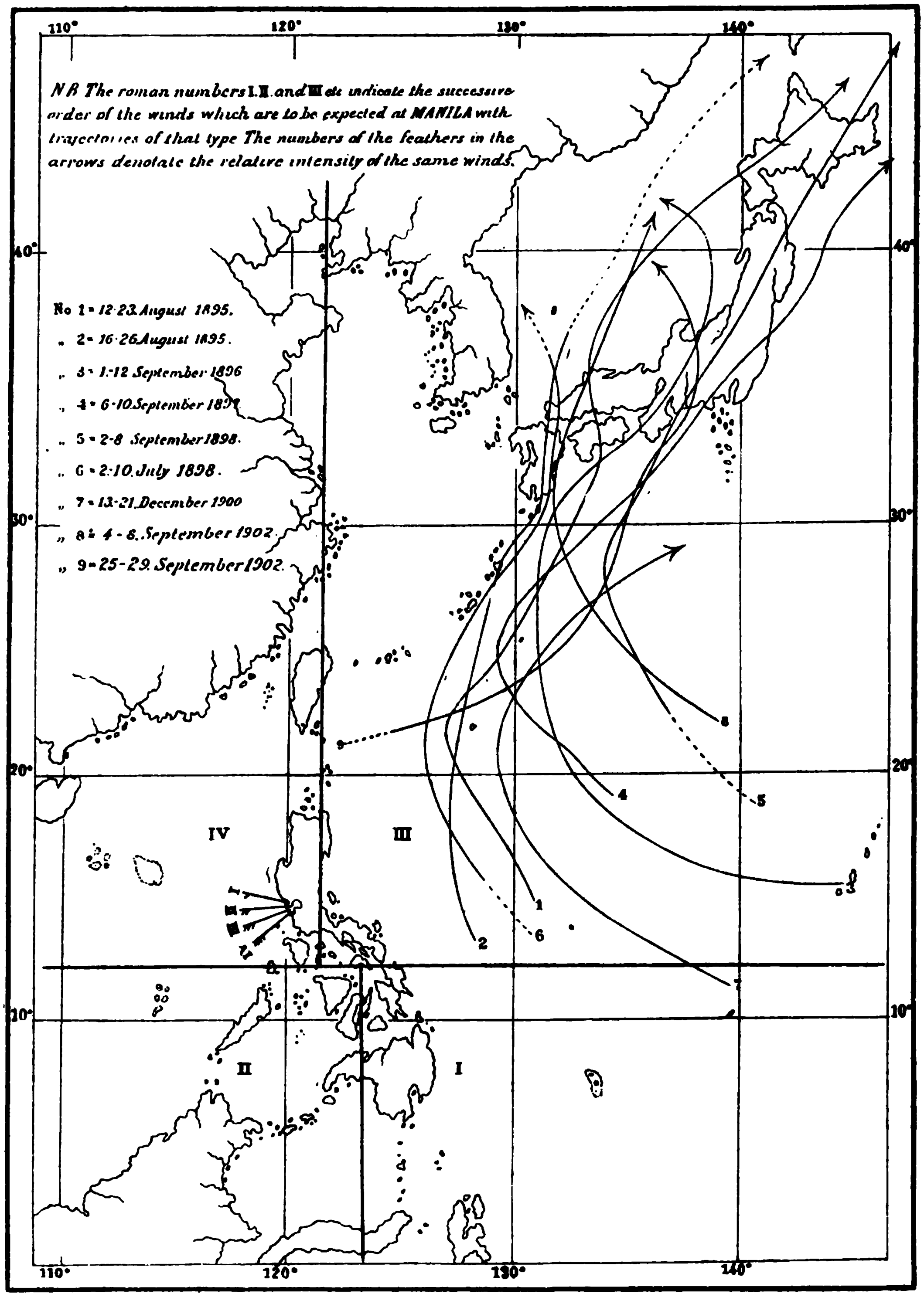

110°
120°
130°
140°
N.B. The arrows indicate the winds which are to be expected at MANILA with trajectories of that type.
40°
No. 1 = 30. October 2. Nov. 1890.
" 2 = 28. Dec. 1892 1. January 1893.
" 3 = 7-12. October 1894.
" 4 = 18-22. November 1895.
" 5 = 18-22. August 1896.
" 6 = 5-14. October 1896.
" 7 = 23-28. April 1899.
" 8 = 12-20. December 1900.
30°
20°
10°
IV
III
II
I
1
2
3
4
5
6
7
8
110°
120°
130°
140°

Longitude E. of Greenwich.

TYPE 2ND

Plate XVIII.

CYCLONES FORMED IN THE PACIFIC, WHICH HAVE RECURVED TOWARDS JAPAN AT SOME DISTANCE FROM THE MERIDIAN OF MANILA.



N.B. The roman numbers I. II. and III etc indicate the successive order of the winds which are to be expected at MANILA with trajectories of that type The numbers of the feathers in the arrows denotate the relative intensity of the same winds.

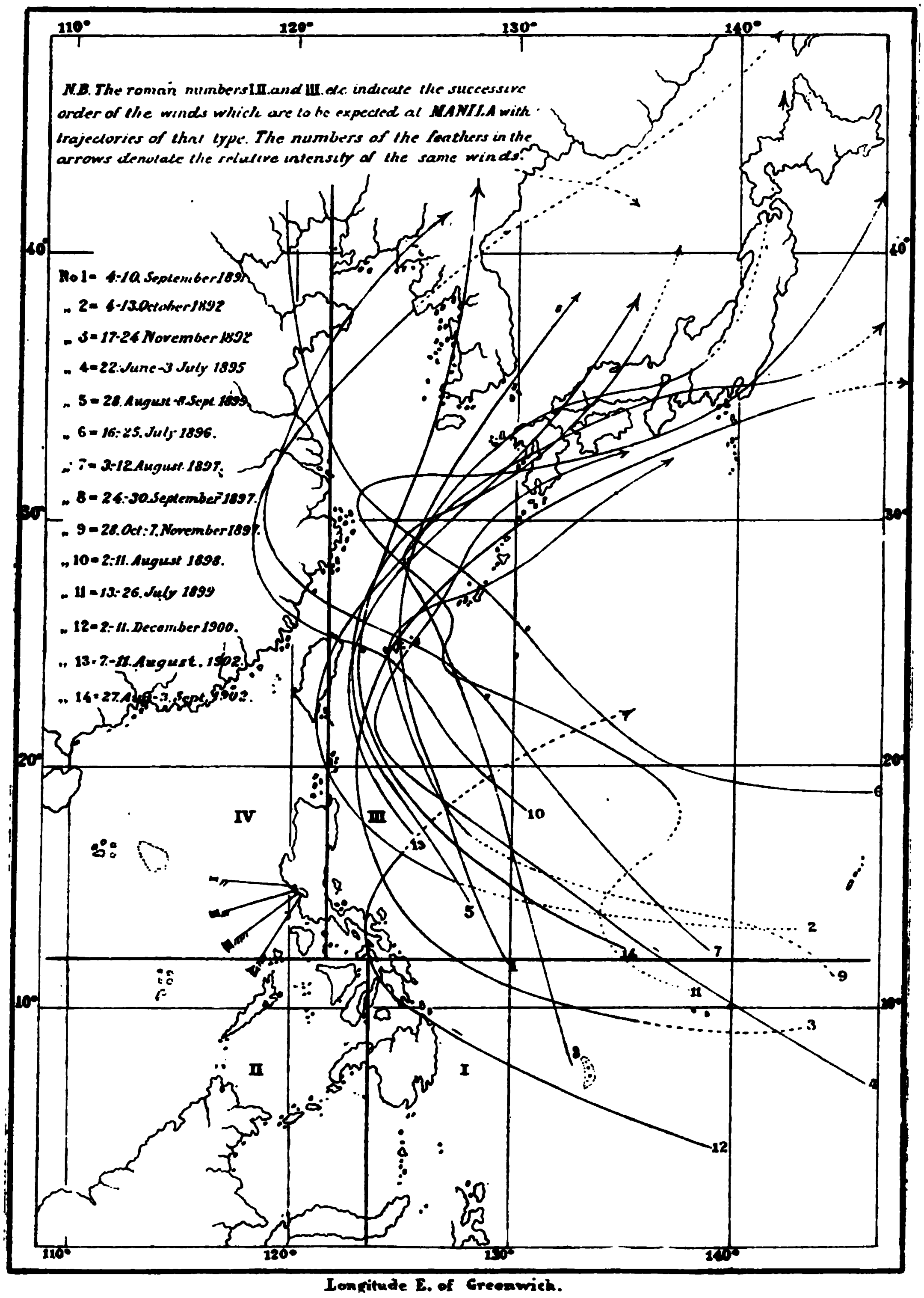
No 1 = 12-23 August 1895.
" 2 = 16-26 August 1895.
" 3 = 1-12 September 1896
" 4 = 6-10 September 1897
" 5 = 2-8 September 1898.
" 6 = 2-10 July 1898.
" 7 = 13-21 December 1900
" 8 = 4-8 September 1902.
" 9 = 25-29 September 1902.

Longitude E. of Greenwich.

TYPE 3RD

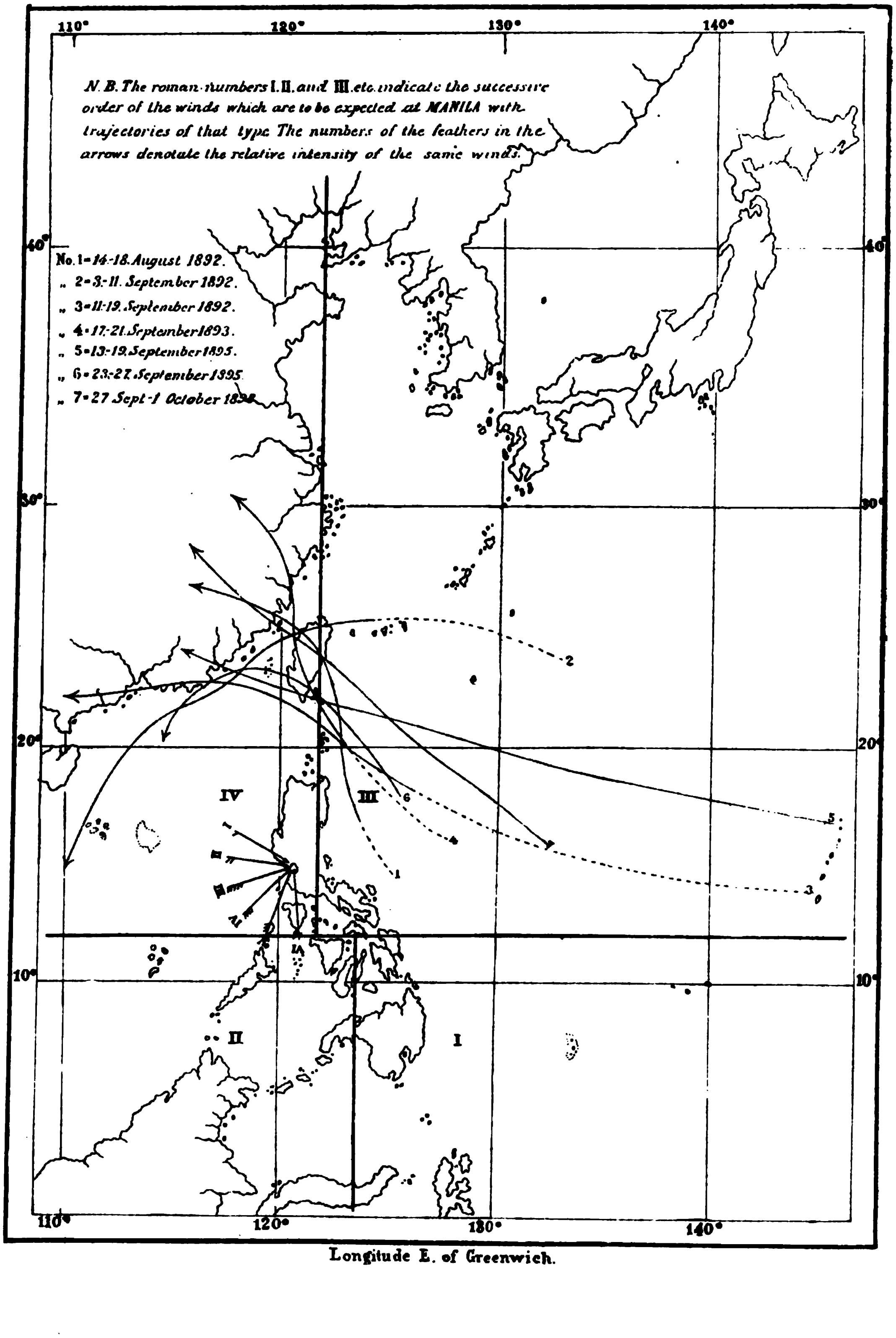
Plate XIX.

CYCLONES FORMED IN THE PACIFIC, WHICH HAVE RECURVED TOWARDS JAPAN NEAR THE MERIDIAN OF MANILA.


N.B. The roman numbers I, II and III etc. indicate the successive order of the winds which are to be expected at MANILA with trajectories of that type. The numbers of the feathers in the arrows denotate the relative intensity of the same winds.
No 1 = 4-10 September 1891
" 2 = 4-13 October 1892
" 3 = 17-24 November 1892
" 4 = 22 June-3 July 1895
" 5 = 28 August-8 Sept. 1895
" 6 = 16-25 July 1896.
" 7 = 3-12 August 1897.
" 8 = 24-30 September 1897.
" 9 = 28 Oct.-7 November 1897.
" 10 = 2-11 August 1898.
" 11 = 13-26 July 1899
" 12 = 2-11 December 1900.
" 13 = 7-11 August 1902.
" 14 = 27 Aug.-3 Sept. 1902.
110°
120°
130°
140°
40°
30°
20°
10°
I
II
III
IV
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Longitude E. of Greenwich.

TYPE 4TH   Plate XX.

CYCLONES OF THE FORMOSA ISLAND.



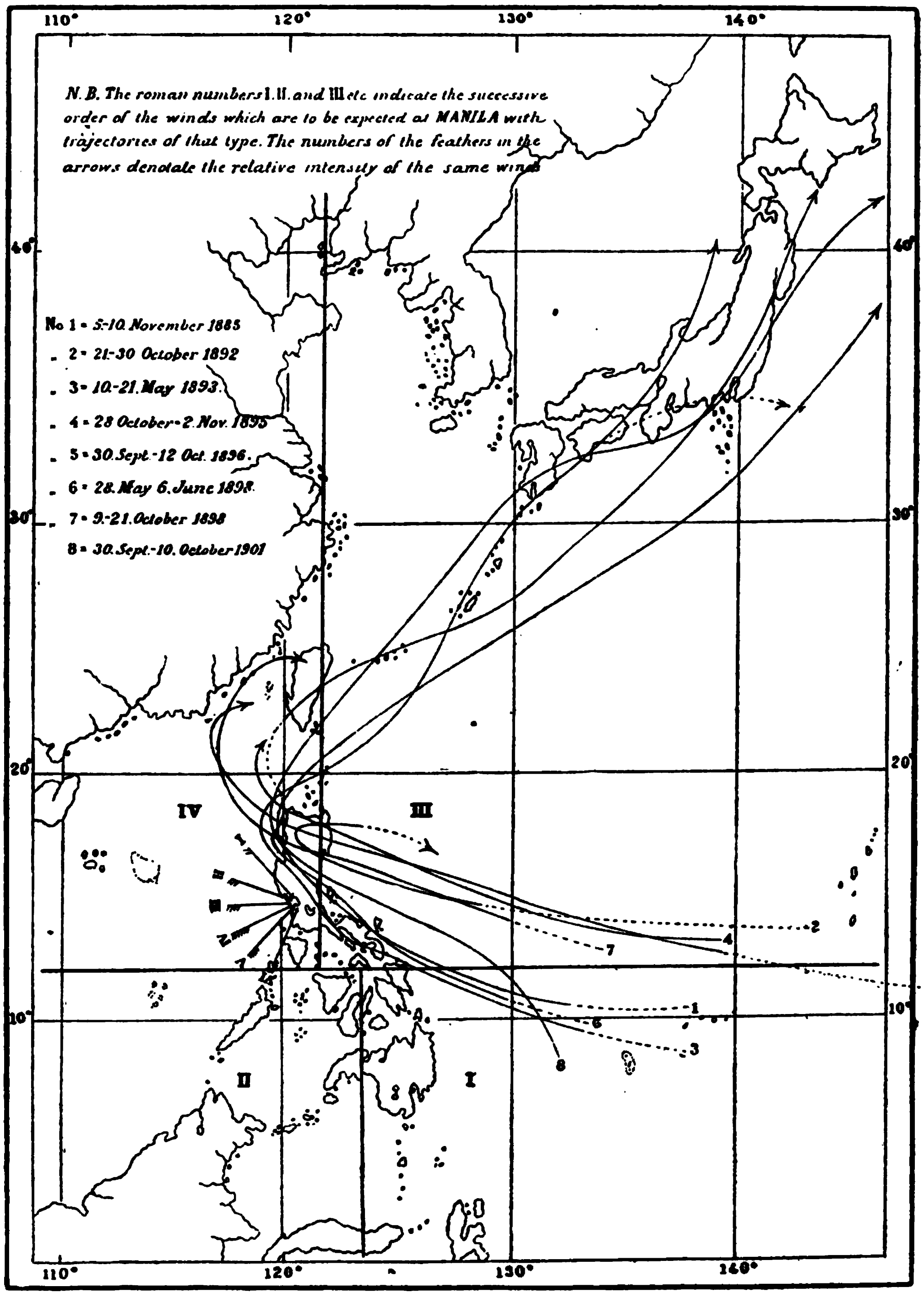
N. B. The roman numbers I. II. and III. etc. indicate the successive order of the winds which are to be expected at MANILA with trajectories of that type. The numbers of the feathers in the arrows denotate the relative intensity of the same winds.

No. 1 = *14-18. August 1892.*
„ 2 = *3-11. September 1892.*
„ 3 = *11-19. September 1892.*
„ 4 = *17-21. September 1893.*
„ 5 = *13-19. September 1895.*
„ 6 = *23-27. September 1895.*
„ 7 = *27 Sept-1 October 1898.*

TYPE 5th

Plate XXI.

CYCLONES OF LUZON WHICH HAVE CROSSED THROUGH THE NORTH OF MANILA AND HAVE A LITTLE AFTERWARDS RECURVED EITHER IN THE INTERIOR OR NEAR THE ISLAND IN THE CHINA SEA

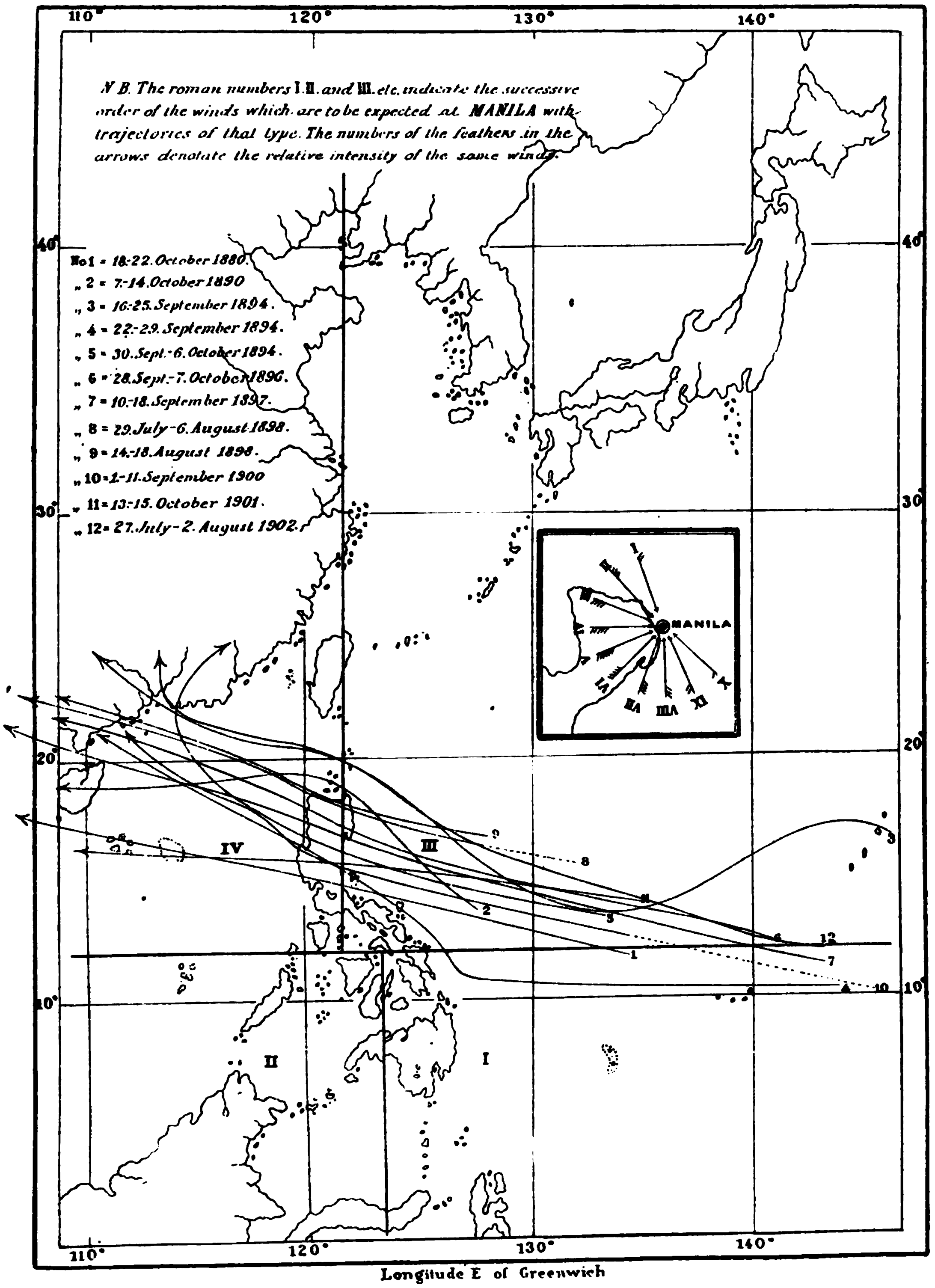

110°
120°
130°
140°
N. B. The roman numbers I. II. and III etc indicate the successive order of the winds which are to be expected at MANILA with trajectories of that type. The numbers of the feathers in the arrows denotate the relative intensity of the same winds
40°
30°
20°
10°
No 1 = 5-10 November 1885
" 2 = 21-30 October 1892
" 3 = 10-21 May 1893.
" 4 = 28 October - 2 Nov. 1895
" 5 = 30 Sept. - 12 Oct. 1896.
" 6 = 28 May 6 June 1898.
" 7 = 9-21 October 1898
8 = 30 Sept. - 10 October 1901
IV
III
II
I
1
2
3
4
5
6
7
8

Longitude E. of Greenwich

TYPE 6TH

Plate XXII.

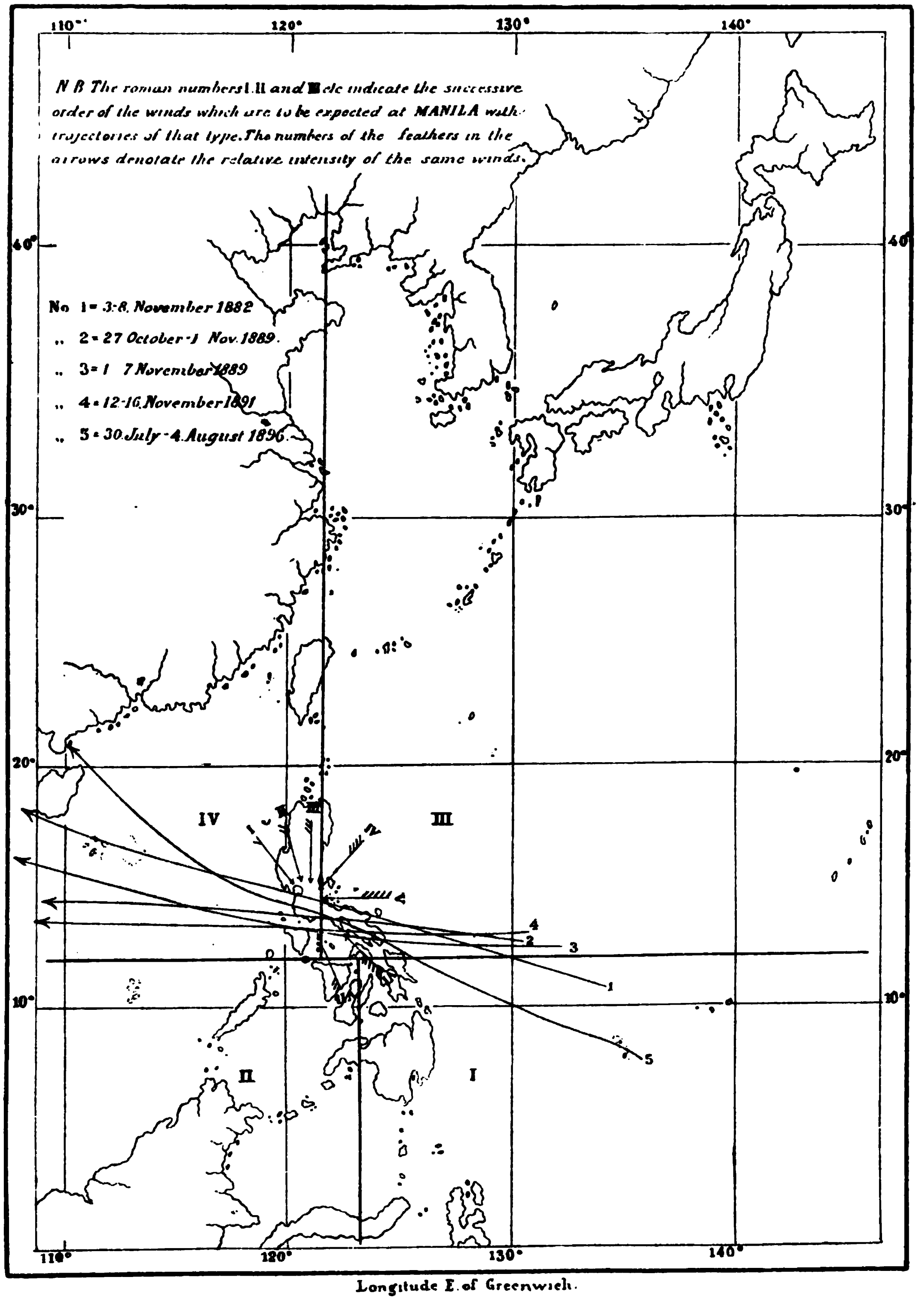
CYCLONES OF LUZON WHICH HAVE CROSSED THROUGH THE NORTH OF MANILA AND HAVE IMMEDIATELY GONE TO THE CONTINENT.


N B. The roman numbers I. II. and III. etc. indicate the successive order of the winds which are to be expected at MANILA with trajectories of that type. The numbers of the feathers in the arrows denotate the relative intensity of the same winds.
No 1 = 18-22. October 1880.
" 2 = 7-14. October 1890
" 3 = 16-25. September 1894.
" 4 = 22-29. September 1894.
" 5 = 30. Sept.-6. October 1894.
" 6 = 28. Sept.-7. October 1896.
" 7 = 10-18. September 1897.
" 8 = 29. July-6. August 1898.
" 9 = 14-18. August 1898.
" 10 = 1-11. September 1900
" 11 = 13-15. October 1901.
" 12 = 27. July-2. August 1902.
MANILA
I
II
III
IV
V
VI
VII
VIII
IX
X
110°
120°
130°
140°
40°
30°
20°
10°
Longitude E of Greenwich

TYPE 7TH

Plate XXIV.

CYCLONES OF LUZON WHICH HAVE CROSSED THROUGH THE SOUTH OF MANILA.



N B The roman numbers I. II and III etc indicate the successive order of the winds which are to be expected at MANILA with trajectories of that type. The numbers of the feathers in the arrows denotate the relative intensity of the same winds.

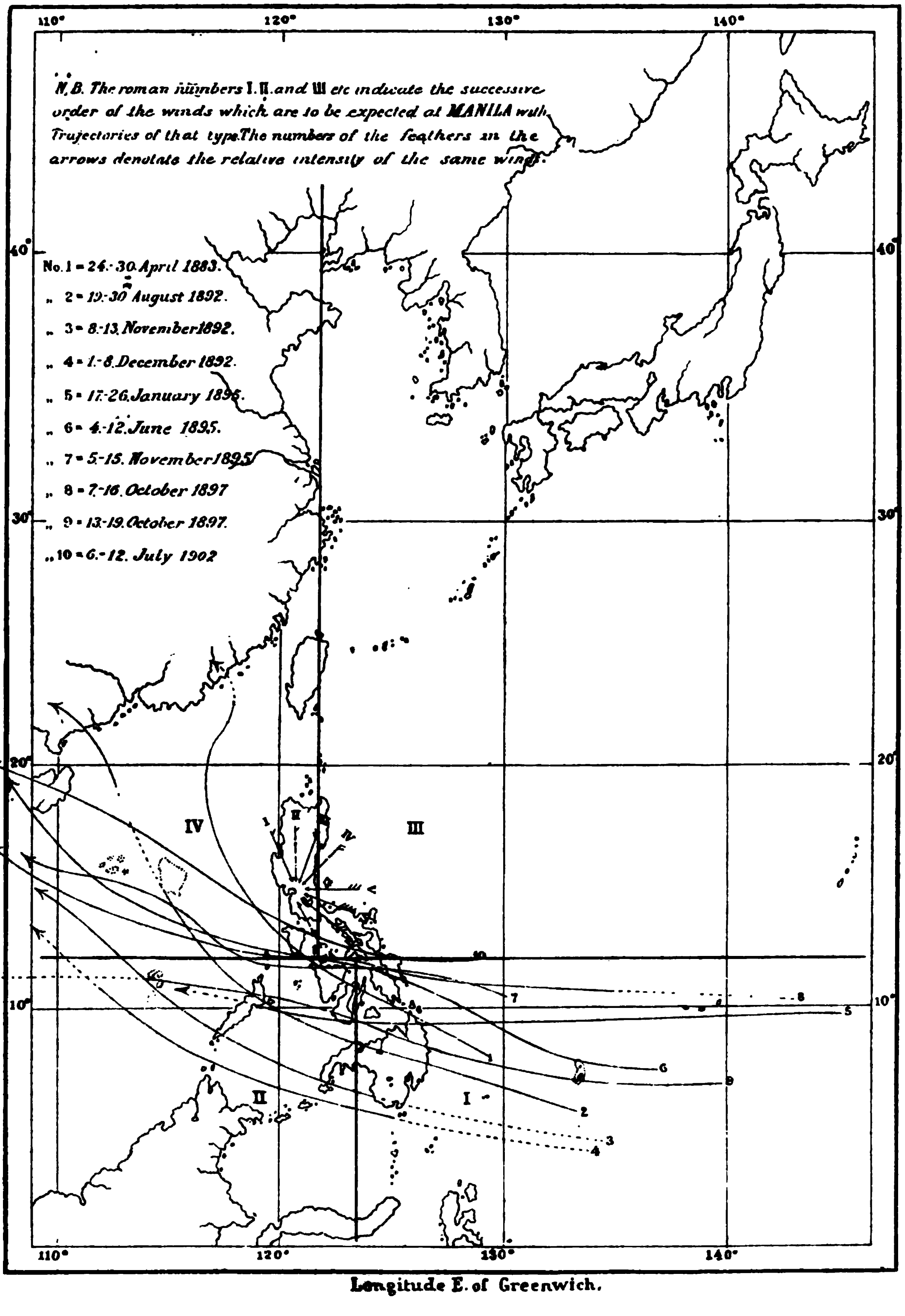
No 1 = *3-8. November 1882*
,, 2 = *27 October-1 Nov. 1889.*
,, 3 = *1 7 November 1889*
,, 4 = *12-16. November 1891*
,, 5 = *30. July - 4. August 1896.*

Longitude E. of Greenwich.

TYPE 8TH

Plate XXV.

CYCLONES OF BISAYAN AND MINDANAO ISLANDS.

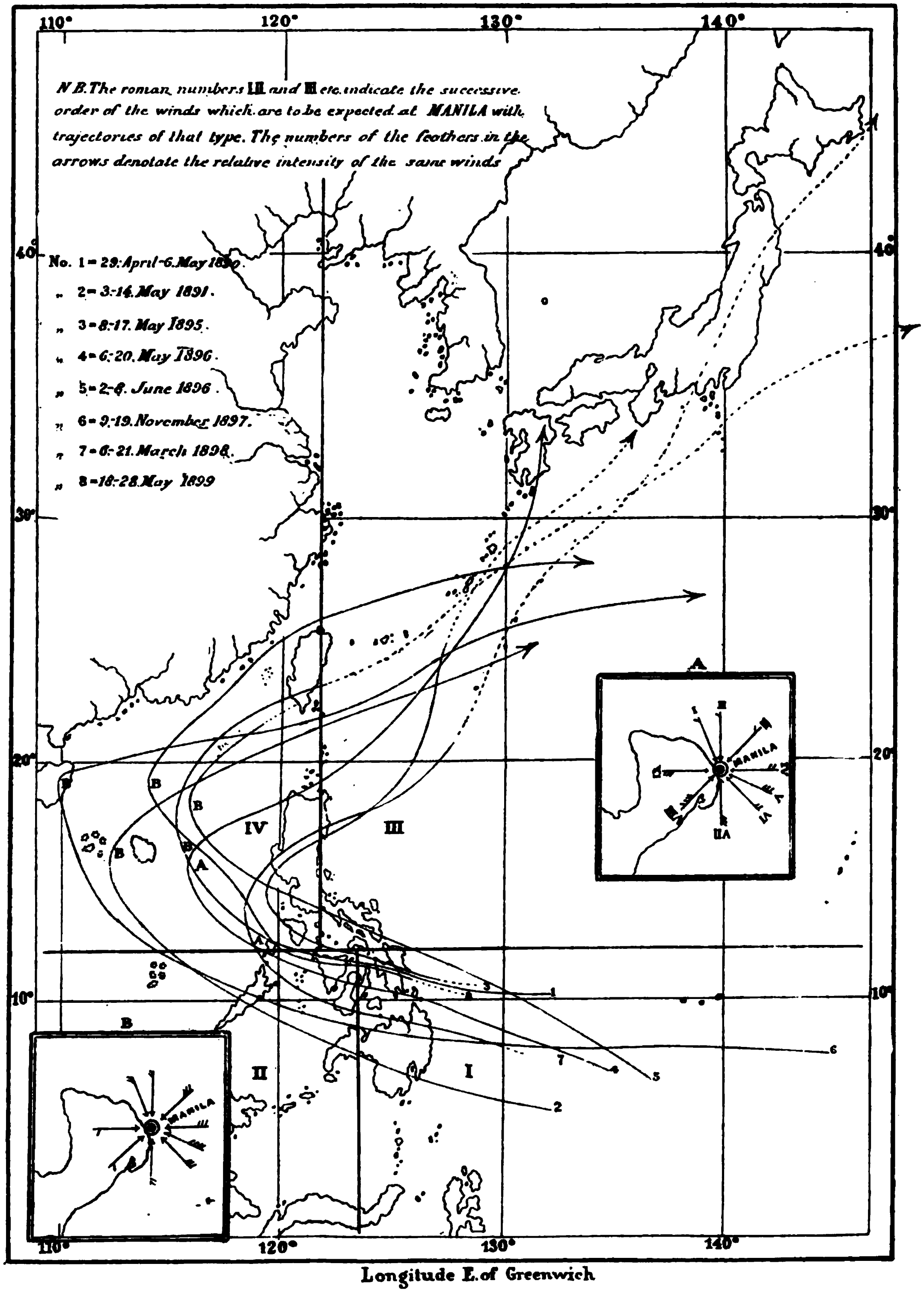

N.B. The roman numbers I. II. and III etc indicate the successive order of the winds which are to be expected at MANILA with Trajectories of that type. The numbers of the feathers in the arrows denotate the relative intensity of the same winds.
No. 1 = 24.-30. April 1883.
" 2 = 19.-30. August 1892.
" 3 = 8.-13. November 1892.
" 4 = 1.-8. December 1892.
" 5 = 17.-26. January 1895.
" 6 = 4.-12. June 1895.
" 7 = 5.-15. November 1895.
" 8 = 7.-16. October 1897
" 9 = 13.-19. October 1897.
" 10 = 6.-12. July 1902
110°
120°
130°
140°
40°
30°
20°
10°
I
II
III
IV
1
2
3
4
5
6
7
8
9
10
Longitude E. of Greenwich.

UNIV. OF MICH.

TYPE 9TH

Plate XXVI.

CYCLONES FORMED IN THE PACIFIC, WHICH HAVE RECURVED IN THE CHINA SEA BETWEEN PARALLELS 10° AND 20° AND HAVE CROSSED BEFORE THE SOUTH AND AFTERWARDS THE NORTH OF THE MERIDIAN OF MANILA.

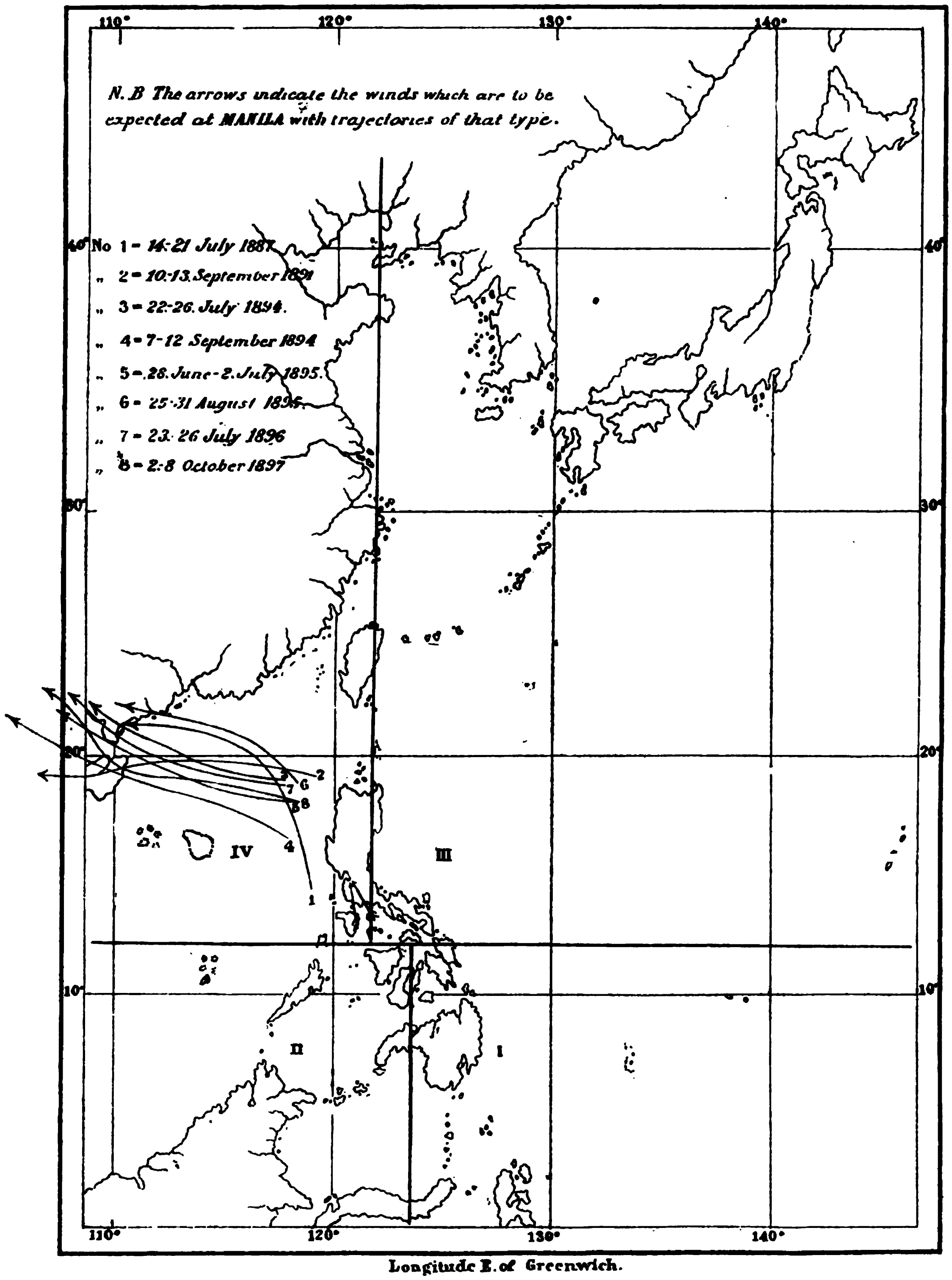

N.B. The roman numbers I, II and III etc. indicate the successive order of the winds which are to be expected at MANILA with trajectories of that type. The numbers of the feathers in the arrows denotate the relative intensity of the same winds
No. 1 = 29: April - 6. May 1890.
" 2 = 3: 14. May 1891.
" 3 = 8: 17. May 1895.
" 4 = 6: 20. May 1896.
" 5 = 2-8. June 1896.
" 6 = 9: 19. November 1897.
" 7 = 6: 21. March 1898.
" 8 = 18: 28. May 1899
110°
120°
130°
140°
40°
30°
20°
10°
A
B
MANILA
I
II
III
IV
1
2
3
4
5
6
7
8
Longitude E. of Greenwich

UNIV. OF MICH.

TYPE 10TH

Plate XXVII.

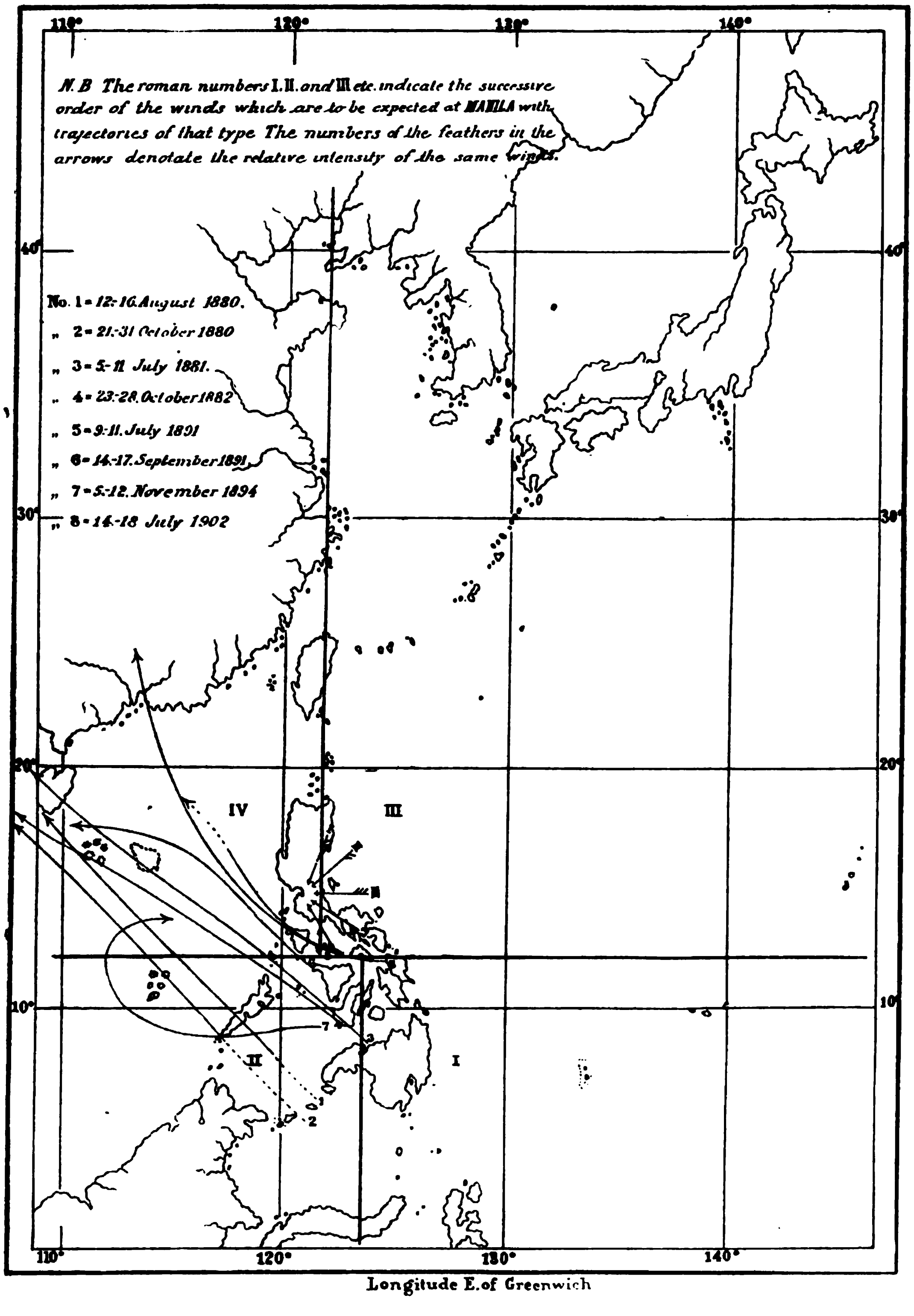
CYCLONES FORMED IN THE CHINA SEA


N. B The arrows indicate the winds which are to be expected at MANILA with trajectories of that type.
No 1 = 14-21 July 1887
" 2 = 10-13. September 1891
" 3 = 22-26. July 1894.
" 4 = 7-12 September 1894
" 5 = 28. June - 2. July 1895.
" 6 = 25-31 August 1895.
" 7 = 23-26 July 1896
" 8 = 2-8 October 1897
110°
120°
130°
140°
40°
30°
20°
10°
1
2
3
4
5
6
7
8
I
II
III
IV
Longitude E. of Greenwich.

TYPE 11TH

Plate XXVIII

CYCLONES FORMED IN THE SEA OF JOLÓ (SULU) AND IN THE INTERINSULAR SEAS TO THE SOUTH OF LUZON.



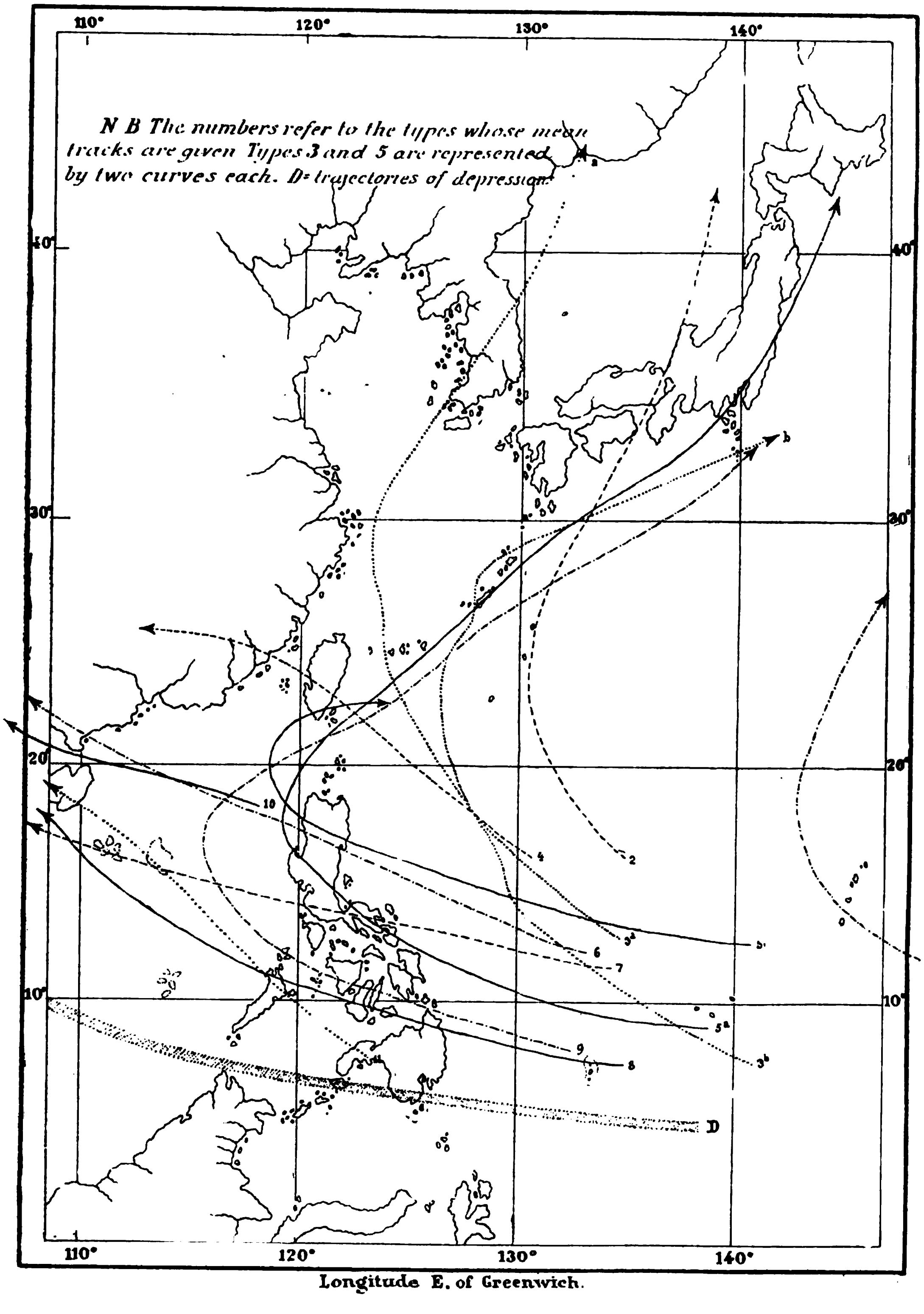
N. B. The roman numbers I. II. and III etc. indicate the successive order of the winds which are to be expected at MANILA with trajectories of that type. The numbers of the feathers in the arrows denotate the relative intensity of the same winds.

No. 1 = *12-16 August 1880.*
" 2 = *21-31 October 1880*
" 3 = *5-11 July 1881.*
" 4 = *23-28 October 1882*
" 5 = *9-11 July 1891*
" 6 = *14-17 September 1891*
" 7 = *5-12 November 1894*
" 8 = *14-18 July 1902*

MEAN TRACKS

Plate XXIX.

OF CYCLONES OF THE FAR EAST.



N B The numbers refer to the types whose mean tracks are given Types 3 and 5 are represented by two curves each. D= trajectories of depression.

PART II. PRECURSORY SIGNS OF CYCLONES.

PART II. PRECURSORY SIGNS OF CYCLONES.

CHAPTER I. THE CLOUDS.

General indications.—Clouds can afford us intimation as to the existence, the position, and movement of a cyclone by their form and structure, their direction and velocity, their altitude, and other characteristics, as for instance, color and amount.

Object of cloud obervation.—Cloud observations, as usually made, include estimates of the amount, form, and movement of clouds. The form and motion of clouds give us the only information we can obtain, without the use of baloons, of the changes in progress in any part of the atmosphere removed from the earth's surface and of the direction and rate of motion of the higher strata. Barometers, thermometers, wind vanes, etc., tell us the conditions (such as, for example, pressure and temperature and direction of motion) of the air at the place of observation only, and hence at or very near the earth's surface.

The existence of a cloud at any elevation indicates that the atmosphere in the space occupied by the cloud is in a state of saturation and that the vapor is being condensed. The shape of the cloud also tells us some of the conditions under which this air space became saturated and the cloud was formed, and hence indicates to some extent changes which are going on in the air above us and may affect the weather at the earth's surface. Finally, their direction of movement shows what winds are blowing high up in the air. The observer is thus enabled by comparing the direction and rate of motion of the air at the earth's surface and at different heights in the atmosphere to ascertain whether the weather is settled or unsettled and what changes in the weather may be expected.

Cloud proportion.—The proportion of the sky covered by clouds is estimated by simple inspection. A sky wholly overcast is recorded as "10" and all minor degrees of cloudiness by the lower numbers from 9 downwards, the figure "0" being used to indicate a perfectly cloudless sky. From the nature of the observation an approximate estimate only is possible, but with a little practice it will be found easy to make it with sufficient accuracy for practical requirements.

Kinds of clouds.—Clouds may be roughly divided in respect of their apparent shape and form into two great classes—first, separate or globular masses (most frequently seen in dry weather) and second, forms which are widely extended or completely cover the sky (chiefly occurring in wet weather). Each of these two forms is subdivided, partly according to their shape and partly according to their altitude.

The following gives the classification of clouds, arranged chiefly in order of their elevation, as used by observers at meteorological observatories in the Philippines.

CLASSIFICATION OF CLOUD FORMS ADOPTED BY THE INTERNATIONAL METEOROLOGICAL COMMITTEE.[1]

[a = Separate or globular masses (most frequently seen in dry weather). b = Forms which are widely extended, or completely cover the sky (in wet weather).]

A. *Upper clouds*, average altitude, 9,000 meters.
    a. (1) Cirrus.
    b. (2) Cirro-stratus.

---

[1] Both classification and explanations are taken from the International Cloud Atlas. Paris, 1896. pp. 13–18.

B. *Intermediate clouds*, between 3,000 and 7,000 meters.
  a. { (3) Cirro-cumulus.
       (4) Alto-cumulus.
  b. (5) Alto-stratus.

C. *Lower clouds*, 2,000 meters.
  a. (6) Strato-cumulus.
  b. (7) Nimbus.

D. *Clouds of diurnal ascending currents.*
  a. (8) Cumulus, apex, 1,800 meters; base, 1,400 meters.
  b. (9) Cumulo-nimbus; apex, 3,000 to 5,000 meters; base, 1,400 meters.

E. *High fogs*, under 1,000 meters.
  (10) Stratus.

EXPLANATIONS.

(1) **Cirrus (Ci.)**.—Detached clouds, delicate and fibrous looking, taking the form of feathers, generally of a white color, sometimes arranged in belts which cross a portion of the sky in "great circles" and by an effect of perspective converge toward one or two opposite points of the horizon. (The cirro-stratus and the cirro-cumulus often contribute to the formation of these belts.)

(2) **Cirro-stratus (Ci.-S.)**.—A thin, whitish sheet, at times completely covering the sky and only giving it a whitish appearance (it is then sometimes called cirro-nebula) or at others presenting, more or less distinctly, a formation like a tangled web. This sheet often produces halos around the sun and moon.

(3) **Cirro-cumulus (Ci.-Cu.)**.—Small globular masses of white flakes without shadows or having only very slight shadows, arranged in groups and often in lines.

(4) **Alto-cumulus (A.-Cu.)**.—Large, globular masses, white or grayish, partially shaded, arranged in groups or lines, and often so closely packed that their edges appear confused. The detached masses are generally larger and more compact (changing to strato-cumulus) at the center of the group; at the margin they form into finer flakes (changing to cirro-cumulus). They often appear spread out in lines in one or two directions. (The title "cumulo-cirrus" is suppressed as giving rise to confusion.)

(5) **Alto-stratus (A.-S.)**.—A thick sheet of gray or bluish color, showing a brilliant patch in the neighborhood of the sun or moon and which, without causing halos, may give rise to coronæ. This form goes through all the changes like the cirro stratus, but by measurements made at Upsala, its altitude is one-half less. (The title "strato-cirrus is suppressed as giving rise to confusion.)

(6) **Strato-cumulus (S.-Cu.)**.—Large, globular masses or rolls of dark cloud, frequently covering the whole sky, especially in winter, and occasionally giving it a wavy appearance. The layer of strato-cumulus is not, as a rule, very thick, and patches of blue sky are often visible through the intervening spaces. All sorts of transitions between this form and the alto-cumulus are noticeable. It may be distinguished from nimbus by its globular or rolled appearance and also because it does not bring rain.

(7) **Nimbus (N.)**—**Rain cloud.**—A thick layer of dark clouds, without shape and with ragged edges from which continued rain or snow generally falls. Through the openings of these clouds an upper layer of cirro-stratus or alto-stratus may almost invariably be seen. If the layer of nimbus separates up into shreds, or if small loose clouds are visible floating at a low level, underneath a large nimbus, they may be described as fracto-nimbus (Fr.-N.), "scud" of sailors.

(8) **Cumulus (Cu.)**—**Wool pack clouds.**—Thick clouds of which the upper surface is dome-shaped and exhibits protuberances, while the base is horizontal. These clouds appear to be formed by a diurnal ascensional movement which is almost always observable. When the cloud is opposite the sun the surfaces usually presented to the observer have a greater brilliancy than the margins of the protuberances. When the light falls aslant these clouds give deep shadows; when, on the contrary, these clouds are on the same side as the sun they appear dark with bright edges.

The true cumulus has clear superior and inferior limits. It is often broken up by strong winds.

and the detached portions undergo continual changes. These may be distinguished by the name fracto-cumulus.

(9) **Cumulo-nimbus (Cu.-N.)—The thunder cloud; shower cloud.**—Heavy masses of clouds, rising in the form of mountains, turrets, or anvils, generally having a sheet or screen of fibrous appearance above ("false cirrus") and underneath, a mass of clouds similar to "nimbus." From the base there usually fall local showers of rain or of snow (occasionally hail or soft hail). Sometimes the upper edges have the compact form of cumulus, forming into massive peaks around which the delicate "false cirrus" floats, and sometimes the edges themselves separate into a fringe of filaments similar to that of the cirrus cloud. This last form is particularly common in spring showers.

The front of thunder clouds of wide extent frequently presents the form of a large bow spread over a portion of the sky which is uniformly brighter in color.

(10) **Stratus (S.)—A horizontal sheet of lifted fog.**—When this sheet is broken up into irregular shreds by the wind or by the summits of mountains it may be distinguished by the name of fracto-stratus (Fr.-S.).

INSTRUCTIONS FOR THE OBSERVATION OF THE CLOUDS.

For each observation the following points are to be noted and entered in the register or schedule.

(1) **The kind of cloud.**—This is indicated by the international letters of the name of the cloud (for greater precision the number of the plate in the atlas which most nearly resembles the form observed might be given)—for example, Ci., 3.

(2) **The direction from which the clouds come.**—By remaining perfectly still for several seconds the movements of the clouds may easily be observed in relation to a steeple or pole erected in an open space.[1] If the movement of the cloud is very slow the head should be steadied by using a rest. This method of observing must only be used for clouds near the zenith, for if they are too distant from it the perspective may lead to errors. In such cases the nephoscope must be used, and in each case the rules given for the kind of instrument in use must be followed.

(3) **The point of radiation of the upper clouds.**—These clouds often take the form of narrow parallel lines, which, owing to perspective, appear to issue from a given point on the horizon. The "point of radiation" is the name given to the point where these belts or their prolongations meet the horizon. This point on the horizon should be indicated in the same manner as the direction of the wind, north, north-northeast, etc.

(4) **Undulated clouds.**—It often happens that the clouds have the appearance of regular striæ, parallel and equidistant, like waves on the surface of water. This is mostly the case with the cirro-cumulus, strato-cumulus (roll cumulus), etc. It is important to note the direction of these striæ. When two distinct systems are apparent, as is often seen in clouds separated into globular masses by striæ in two directions, the directions of those two systems should be noted.

As far as possible, these observations should be taken of striæ near the zenith, so as to avoid errors caused by perspective.

(5) **The density and situation of a bank of cirrus.**—The upper clouds often assume the form of a tangled web or sheet, more or less dense, which, as it appears above the horizon, looks like a thin bank of a light or grayish color. As this form of cloud is closely connected with barometrical depression it is necessary to observe:

a. The density.
    0. Very thin and irregular.
    1. Thin, but regular.
    2. Fairly thick.
    3. Thick.
    4. Very thick and of a dark color.
b. The direction in which the sheet or bank appears thickest.

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[1] M. Broounof points out that it is a very convenient plan to have a pole bearing a horizontal cross with its arms pointing N.-S. and E.-W., respectively.

(6) **Remarks.**—All interesting particulars should be noted, such as:

(*a*) During the summer all low clouds, as a rule, assume special forms, resembling more or less cumulus. In such cases an entry should be made in the column for "remarks," stratus or nimbus cumuliformus.

(*b*) It sometimes happens that a cumulus presents a mammillated lower surface. This appearance should be noted under the name of mammato-cumulus.

(*c*) It should always be noted whether the clouds seem to be stationary or in very rapid motion.

Two large divisions of cloud forms.—The general cloud types can be classed into two large divisions: (1) The cumulus clouds, which are formed by vertical convection—that is, the transportation of air from one level to another; and (2) the stratus clouds, which are due usually to the flowing of two currents of air over each other, while the temperatures are different in the adjacent layers. The former type indicates an effort to restore the normal equilibrium proper to the season and the locality by carrying the excess of heat from lower to higher levels; the latter shows that there is a stratified condition of the atmosphere, with strata of distinctly different temperatures, which are being transported by horizontal convection gradients from one place to another. The two processes include all the general actions that operate in the readjustment of temperature equilibrium when the differences have been caused originally by insolation and radiation.

The several intermediate types are evidently caused by the interaction of these primary processes in greater or less proportion, and it is not difficult to analyze them approximately on this basis. The alto-cumulus type indicates the presence of a warm stratum at a high level, within which vertical convection occurs to a moderate amount; the ordinary cumulus must be the result of more extensive vertical movements, and these occur in the warm parts of the day, especially during summer when there is much heat accumulated by insolation at the surface to be disposed of in a higher stratum; the cumulo-nimbus are caused by exaggerated heat conditions in the lower levels, and the towering domes with boiling vortex motions so characteristic of them show also that the general circulation is on such occasions quite stagnant from the ground to the cirrus region and that the eastward drift (in temperate zones) is then locally much diminished, which condition occurs chiefly in the hot days of the summer.

Clouds as indications of cyclones.—The upper clouds and in a less degree the clouds of medium height give us information as to the existence of a cyclone before it has reached the place of observation. Hence they are true harbingers: the other kinds of clouds reveal by the direction of their motion and form the place where the center is located as soon as a zone of the cyclone has reached the place of observation.

Cirrus and cirro-stratus as signs of a cyclone.—Before discussing the value of these cloud formations as heralds of a cyclonic storm it is necessary to touch upon a meteorological question of greatest interest, to wit: Is the convergence so frequently shown by delicate feathery streaks of cirrus always only apparent, a mere effect of perspective? The description of cirrus above quoted from the "International Cloud Atlas," as well as Number three of the "Instructions for the observation of the clouds," taken from the same source, seem to take it for granted that the phenomenon in question is never anything but an optical illusion. But this is assuming too much, as there is nothing to assure us that these streaks always arrange themselves objectively parallel. On the contrary, as each of the tufts assumes most various shapes so do they group themselves in widely different ways. They have been observed forming zig-zag lines: we have seen them build up arches with fluted outlines; sometimes they appear in the form of ramified fringes, resembling feathers; nor is it rare to behold small annular shapes interlaced like the links of a chain; sometimes the fringes seem to be tubular and undulating. If such formations are observed near the zenith there will indeed always be noticed a certain symmetry in the distribution of the streaks of cirrus, but they are very far from being always parallel: many times they will exhibit a convergent tendency toward points near the zenith, and in such cases their convergence can not be attributed to an effect of perspective. Hence follows:

(*a*) The streaks of cirrus are, at least in some instances, really convergent toward a given point of space, and this we believe to be the case with the cirri which issue from a cyclonic vortex. Though the latter is not a point, on the contrary may have—according to what has been said in Part I—considerable dimensions, especially in its upper portions; still for practical purposes it may be considered as the vortex of the angle formed by the cirrus clouds if their lines were prolonged until they met. Especially if the observer is very far distant from the vortex—as he always is when there is question of the first indications of an approaching typhoon—the error is not appreciable.

(*b*) The streaks of cirrus are sometimes parallel, which may be due either to atmospheric electricity according to Howard, Forster, Peltier, and others, or to some dynamic effect of the upper air currents, which latter hypothesis seems more probable according to explanations advanced by Bravais and Lamark. An interesting essay touching upon this subject of orientation has been published by Rev. B. F. Valladares, S. J., director of the observatory of Oña, in the publication of said observatory for 1895 (Oña, 1896).

Both classes of cirri, the convergent and the parallel, we call orientated. Both have a close relation to the position of the cyclonic vortex, the convergent cirri directly, the parallel cirri indirectly. We are also inclined to the belief that the latter float usually at smaller altitudes than the former. The reason for this opinion we find in the fact that in the case of parallel cirri the angles formed by the direction of their movement with the direction of their orientation varies between considerable values, while in the case of convergent cirri this angle is invariably small, at least in the Tropics.

Consequently, from the point of view of the weather forecaster, the study of the characteristics of convergent cirri is much more important than that of the parallel cirri. The latter, however, appear much more frequently in higher latitudes, and on this account their observation may prove very valuable within higher parallels, as appears from the essay mentioned.

(*c*) But since cirri are often parallel and nevertheless appear convergent if they stretch far away toward the horizon, how can we distinguish apparent convergence from the real? After all, this distinction is not over-difficult. In the case of apparent convergence the streaks appear much more curved, the arches turn their concave sides toward the observer, and the distance of the streaks is invariably greatest at the zenith, so much so that if the cirri extend sufficiently beyond this point there appear to be two points of convergence, one on either side of the zenith. In case the parallel streaks of cirri are short there still is a means of distinguishing the effect of perspective from true convergence. For if the convergence is an optical illusion there will be noticed a great difference of the convergence of those cirri that lie along the great circle passing through the zenith of the observer and the point of apparent radiation and that of the other cirri, a difference which is not so marked if the convergence is real. Fortunately we have, at least in the Tropics, another almost infallible criterion of true convergence, which consists in the direction in which the cirri move; if they come from the point of convergence this convergence is real, because there are hardly any instances of parallel cirri moving in the direction of their orientation.

After these preliminary remarks we proceed to inquire into the importance of cirrus formations for the forecasting of typhoons.

That cirrus and cirro-stratus clouds do give warnings of tropical cyclones can not be doubted, considering the testimony of painstaking observers and eminent meteorologists such as Fr. Viñes with regard to the hurricanes of the Antilles and Fr. Faura as to the cyclones of the Philippines. It is admitted by Ferrel,[1] Abercromby,[2] and several others.

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[1] "A Popular Treatise on the Winds," p. 300.

[2] "Weather," a popular exposition of weather changes from day to day, London, 1887, and "Modern Developments of Cloud Knowledge," 1887.

But we may ask:

(1) Do cirri and cirro-strati always indicate a typhoon, i. e., even when not orientated? Evidently not, because frequent observations have convinced us that they appear often without any important atmospheric alteration following.

(2) But are orientated cirro-stratus clouds and convergent cirri unmistakable signs of cyclonic storms? Some maintain it, not without good reasons. However, to avoid confusion we must distinguish between false cirri and true cirri. The former only indicate a squall. The existence of false cirri makes it necessary to exercise great caution in applying the rule regarding the convergence of cirri, because sometimes it is well-nigh impossible to distinguish the true cirri from the false. This is especially true of observations at sea; at a fixed observatory equipped with first-class instruments the matter is different. Still even at sea careful and persistent observation can dispel the doubt as to the nature of the cirri observed, they being true cirri if the convergence remains for a long time and also the point of radiation is constant.

(3) Are the cirrus and cirro-stratus in the higher latitudes—say, beginning with the twenty-eighth parallel—indications of a storm? A few examples may answer this question. When I was in Havana in February, 1893, I noticed with Fr. Viñes an arborescent ramification of cirrus and cirro-stratus which was convergent toward the north-northwest. The great persistence of this convergence and a quick shift of the great tuft of cloud toward the north and north-northeast convinced us that we had to do with cirri radiating from a center which was crossing the North American Continent in higher latitudes. And this was really the case, for on the following day the telegraph informed us that a terrible snowstorm, a veritable cyclone, had passed at a considerable distance to the southward of New York; the center was over 600 miles distant from Havana.

Another instance is taken from the cyclones of 1896. During the second decade of July several typhoons crossed the Pacific; we select two of these. The first formed between the Marianas and the Western Carolina Islands between July 13 and 14. After having fully developed on the 15th, it first turned toward the north, but next toward the west-northwest, crossing on the 16th the meridian of Yap at a considerable distance to the north. On the same day a second center appeared to the east of the Visayas, which was formed either by the influence of the cyclone, or else was due to some other causes. As both cyclones were present at the same time in the Archipelago on the 17th, the state of the atmosphere appeared very complicated. The barometer fell, but it was impossible by its fall and by the direction of the lower air currents to come to a conclusion as to the bearings of the two centers. However, the upper air currents indicated them. On the 17th we noticed an arborescent ramification of cirrus which was convergent toward the east. On the 18th the local weather report of the Observatory published the following notice:

> **The atmospheric pressure shows a general fall which took its origin in the easternmost part of Luzon. There is a depression in the northeast of the Island.**

During the afternoon a convergence of the cirrus clouds toward east-northeast was noticeable; the following heights and the direction of the clouds were ascertained by a photographic method: Time of observation, 9.15 a. m.: Altitude of cirrus (Group I), 11,192 meters; altitude of cirrus (Group II), 11,003 meters; direction, northeast; velocity, regular.

No doubt they were true cirri, coming from a cyclone. Observations which arrived subsequently confirmed the idea that there was a center of a cyclone on those days and in the indicated direction; and as the same location of the spot was determined at places far distant from Manila, as for instance at Aparri, and the same convergence of cirri was also noticed, it follows that the great tuft of cloud mentioned could not have consisted of false cirri. The cyclone took a northerly direction after the 17th; we were able to conjecture this by the movements of the radiating point of the cirrus clouds. It shifted from east to east-northeast and northeast; these are movements which cirrus, under normal conditions, never shows, and hence they furnish another confirmation of the conjecture that these cirri were of cyclonic origin. The center of the cyclone, moving northward, in all probability came closest to the north coast of Luzon on the afternoon of the 18th.

Hence it follows that the cirri which were observed were emerging from the center of the cyclone and showed themselves at any rate at a considerable distance in the left semicircle. There is no reason to suppose that a cyclone loses its apparatus of cirri whilst it moves in higher latitudes; on the contrary, they probably continue to issue from the vortex, though local circumstances, especially the heavy cloud covering of the sky, may often interfere with observation. This was the typhoon which traveled as far as the Yellow Sea and which obtained a melancholy notoriety through the loss of the German gunboat *Iltis*.[1]

The other typhoon, which made its appearance opposite to the eastern Visayas, was most likely in process of development up to the 18th of July. On this date Surigao showed the lowest atmospheric pressure; on the 19th the barometer reached its lowest point in Calbayog (Samar) and at Albay; the center was therefore already east of Manila. This typhoon was also characterized by tufts of cloud which rose from the center; they were observed in Manila on the 19th, and they exhibited a considerable convergence toward the east. The altitude of the cirri, as measured by means of photographic apparatus, was 13,342 meters.

(4) Faura describes in his essay, "Señales precursoras de temporal en el Archipiélago filipino," the character which the cirrus and cirro-stratus exhibit and what is their value. He writes:

> The best means for determining the center and for following up its movements are the observations of cirri, little clouds of a very fine structure and clear opal color, which appear as elongated feathers, and which are known among sailors as "cocktails." Fr. Viñes, the director of the observatory in Havana, was the first to propose the idea of using these clouds in order to determine the position of the center. This idea is, according to our opinion, one of the greatest conquests achieved in the study of meteorological phenomena during these last years. It must be confessed that in our locality these phenomena do not appear with the clearness and distinctness attributed to them by the author, and for this reason we will tarry a little in describing the characteristics which they usually exhibit in our Archipelago. Long before the least sign of bad weather is noticeable and in many cases when the barometer is still very high, being under the influence of a center of high pressure which generally precedes a tempest, these small isolated clouds appear in the upper regions of the atmosphere. They seem to be piled up on the blue vault of heaven and drawn out in the direction of some point on the horizon toward which they converge. The first to present themselves are few in number, but well defined and of the most delicate structure, appearing like long filaments bound together, but whose visibility is lost before they reach the point of radiation. We often had an opportunity to watch them at the Observatory of Manila, when the center was still 600 miles distant. We must not lose sight of them as soon as we notice them, and we must follow up all the movements which they successively exhibit.
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> The best times for observing the cirri are sunrise and sunset. If the sun is in the east and very near the horizon the first clouds which are tinged by the solar rays are the cirro-strati which precede the cyclone, and they are also the last to disappear at sunset, inasmuch as they overspread the horizon. Such times are the best for determining the radiant point of the cloud streaks, and at the same time for ascertaining the direction in which the center lies. Later on the delicacy of the form, which characterizes this class of clouds in its earlier stages, is lost, and the clouds appear in more confused and entangled forms, like streamers of feather work, with central nuclei, which still maintain this direction, so that the point of radiation can still be detected.
>
> In order to ascertain approximately the direction in which the center is advancing in its movement of translation, it is necessary to determine the changes of the radiant point, at equal intervals of time, and to compare them with the movements of the barometer.
>
> Let us suppose that the point of convergence in which these clouds meet, or in which they would meet if seen in their entire length, lies in the second quadrant, which is the only situation which may become dangerous for an

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[1] This typhoon has been minutely described by Fr. A. Froc in an essay, "The Iltis Typhoon; Zikawei, 1896." On page 12, when speaking of the indications of the typhoon, the author says: "The first sign is incontestably the swell, for the appearance of cirri, a valuable indication pointed out some years ago by Rev. B. Viñes, S. J., for the Antilles, and by Rev. F. Faura, S. J., for the China Sea, can not really be given seriously as a general forerunner for the seas of the Far East, at least to the north of the 28th parallel; these clouds may appear when no typhoon is in existence, and also typhoons make their appearance without being preceded by such cirri." If we admit that in the central part of a cyclone aerial ascending currents exist in such a way as we have explained the matter in the first part of this book, we can not for a moment deny the existence of cirrus rising from the center. Whether the cirrus is visible or not depends on the amount of clouds. The general currents of the atmosphere in the upper region can likewise make their influence felt in such a way that the cirrus may or may not precede the center. (Compare Ferrel, 1 c. p., 302.) Neither Viñes nor Faura mention that *all* cirri are indications of a cyclone; they are so only under certain circumstances, viz. in case of their being convergent and then showing a certain definite disposition.

observer situated in the west of the storm. If the point of convergence does not perceptibly change its position but remains fixed and immovable for a long time, even for several consecutive days, it is almost certain that the tempest will break over the position of the observer. In this case the barometer begins to fall shortly after the first cirrus clouds have been observed and sometimes even before. At first it falls slowly, without completely losing the diurnal and nocturnal oscillatory movements, but changing somewhat the hours of maximum and minimum. The mean daily reading is observed to be each day less than that of the preceding day. That part of the horizon in the direction of the storm begins to be covered by a cirrus veil, which increases slowly until it forms an almost homogeneous covering of the sky. This veil is known by the name cirro-pallium of Poëy, and is that which causes the solar and lunar halos, which are never absent when a storm approaches. Beneath this veil a few isolated clouds, commonly called "cotton," appear. They are much more numerous and larger on the side lying toward the storm where they soon appear as a compact mass. At such times the sunrises and sunsets are characterized by the high red tint which the clouds assume, resembling a great fire, especially in the direction of the cyclone.

The colors are not homogeneous but often present a marked gradation, the most compact part being blood-red, the cirrus veil much lighter in color, finally the cirro-stratus above the veil being colored with still lighter tints. As has already been said, the cirro-strati are usually the last to disappear. If a careful observation is taken at this moment it will be seen that the cirro-stratus clouds form an arc at the point where they are intercepted by the densest part of the cloud. The vertex of this arc exactly corresponds to the direction of the center of the storm. In the case supposed, that is to say, when the direction of the cirro-stratus clouds has not changed after all the phenomena described, it may be taken as certain that the tempest approaches directly toward the observer. The barometer then completely loses the diurnal and nocturnal oscillations; instead of rising at the hours indicated it falls, or at least remains stationary, if the storm is of little importance, or slow in its progress.

The wind remains fixed at one point, generally between northeast and northwest, showing only a few variations which are due principally to the squalls which continually exert their force within the limits of the storm. If the observer is on land or near to it this variation may be the effect produced by breaks in the mountain ranges. The low or cotton clouds return successively, and from time to time cover the sky, throwing out occasional squalls of rain and wind, but the squalls having passed a lull ensues, the cirrus veil remaining, and likewise the hurricane bank of clouds, which seems fixed to the same spot in the direction of the storm. This state of the atmosphere continues until the bank of clouds invades the point of observation in which case the squalls will be continuous and the wind will increase in violence each moment. The phenomena occurring during the height of a tempest need not be described as they are so well known.

This first case, although most to be feared is, however, the rarest and being very easy of observation because the nature of the phenomena indicated is clearly marked it is consequently the easiest to escape from. Suppose in the second place that the cirro-stratus clouds are indeed observed converging toward the second quadrant, e. g., to the southeast, but instead of the point of convergence remaining fixed as in the first case, it successively changes its position. If this change is notable it may be considered certain that the observer is outside of the trajectory. If it changes to the south-southeast and south, the vortex of the cyclone will pass to the south and southwest of the observer; if it changes to the east-southeast and east, the vortex will pass to the northeast and north. The phenomena of the cirrus veil, the solar and lunar halos, the coloration of the clouds by the sun's rays, etc., will also be present, but somewhat modified, according to the position of the vortex of the storm.

The best method, then, for determining the extent to which the storm may affect the observer is the comparison of the movements of the barometer with the rapidity with which the location of the point of convergence of the cirro-stratus clouds changes. If the point of convergence reaches the east or south without the barometer having felt its influence and without complete alteration of the diurnal and nocturnal oscillations, it may be considered certain that the place of observation will only come to lie on the periphery of the storm or, at the worst, will describe a small chord of its horizontal section. In this case only puffs of wind will be felt, or winds from the third quadrant if the vortex passes from the south. The veering of the winds takes place with regularity and in accordance with the known law of storms; those from the fourth and first quadrants being light, while those from the third and second are more brisk and accompanied with showers. These, as we have already said, are in our opinion the winds which constitute the phenomenon known here as the "collas."

There are numerous instances which we could adduce in confirmation of what has been said, but we shall confine ourselves to very few. The month of October, 1881, furnishes two cases which are of special interest on account of the fact that they were observed, the one before, the other after the passage of a typical cyclone across the meridian of Manila, an occurrence which is rare in other latitudes. We simply quote the observations as published in the Bulletin of the Observatory for October, 1881:

October 10.—The sky was covered with cirrus clouds during the whole day; in the forenoon there was a fine solar halo; some feather-like tufts of cirro-stratus converge to east-southeast. (Toward this point of the compass there was a cyclonic vortex.)

October 13.—This morning the cirrus veil belonging to the rear of the cyclone is observable; drizzle at dawn. Persistent cirri till the afternoon, and above it some clearly defined cirro-stratus clouds are visible, which exhibit a slope toward northwest, the position of the center.

October 16.—The sky is alternately overcast and clear; in the afternoon tufts of cirri converging to the south-southeast. These last on through the succeeding night, which was otherwise fine and clear, but a fresh cyclone center shows itself in the south-southeast. During the night a dense cirrus veil began to spread itself under the cirrus, and this gave rise to a faint halo round the moon in the early morning.

October 20.—The storm continued throughout the day, because of the slowness of its forward movement. As the night wore on the squalls from south-southwest gradually ceased, and the winds continued veering to southeast. At daybreak appeared a multitude of cirro-stratus clouds forming gigantic streamers, all converging toward west-northwest, the position of the center. At sunrise all the clouds took on a brilliant orange yellow color, presenting a lovely spectacle.

In November, 1891, four depressions visited Manila; two appeared in the south between the 12th and the 17th, and these caused more destruction than any other storms in the year; two others came between the 16th and the 20th. The first hurricane came from the Pacific Ocean and recurved to the east-northeast of Manila; the second was apparently formed in the neighborhood of the Visayas. Although the conditions were complicated, the observations of cirri given in the Bulletin afford information sufficient to indicate the positions of the cyclone centers.

November 12.—During the day there was a corona round the sun and a convergence of the cirrus clouds toward the southeast (the position of the first center).

November 14.—At night a convergence of the cirrus clouds toward the south (the second center).

November 15.—Solar halo, rainbows, and branching off of the cirri toward southeast in the afternoon, and at night there were cirro-stratus streaks converging to southeast by south, and a lunar corona.

November 18.—Convergence of cirri toward east during the day; at night lunar halo. (Convergence toward the Pacific cyclone.)

We shall give in addition two remarkable instances of convergence, both in front and in the rear of a cyclone.

Typhoon of November 4 and 5, 1882.—Another well-defined convergency fell under observation at this Observatory in front of the typhoon which was felt in Manila on November 4 and 5, 1882.[1]

Fr. Faura thus describes the phenomena in his "Ligeros apuntes sobre el temporal de 4 y 5 de Noviembre de 1882 á su paso sobre Manila":

The first indications of the storm appeared at 9 o'clock on the morning of the 3d; the barometer at this hour registering 759.75 millimeters (29.911 inches). Very far indeed from indicating by itself that such a phenomenon should exist, and for that reason we were unable to avail ourselves of it to predict the storm. But there was discerned in the high regions of the atmosphere a large amount of cirro-stratus in the form of prolonged and crowded filaments which were observed to converge toward the east-southeast, the cumulus clouds being noticed scattered here and there throughout the horizon crossing under the cirro-strati almost at a right angle. At first we believed that the cirro-strati were produced by a whirlwind which was forming on the eastern horizon, but on noticing for many consecutive hours the persistency of the convergence in the horizon, and that they were increasing every moment instead of decreasing, we were convinced that we must recognize another cause more tenacious and of greater importance than a simple and transitory storm. At 11 there commenced to extend under the cirro-stratus a light cirrus veil, giving rise to a beautiful solar halo which remained the rest of the day and was always visible when that part of the atmosphere in which it was formed was left free by the numerous and immense cumuli which frequently occupied all the heavens, crossing, as we have previously said, at right angles under the plumiform cirro-stratus. The barometer which at 9 a. m. registered 759.75 millimetetrs (29.911 inches) fell to 756.52 millimeters (29.786 inches) at 3.15 p. m., in other words, more than 3 millimeters, a circumstance which indicated, according to No. 9 of the "Señales precursoras de temporal," that there was an atmospheric disturbance in the neighborhood. We impatiently awaited the setting of the sun, and this was truly surprising and brought us out of the perplexity in which we found ourselves. From the northeast to the southeast the clouds began to glow near the horizon with a dark but intense red; and whilst the sun was setting, the highest clouds also took on the red color but of a clear and more vivid hue: everything appeared to be involved in one vast conflagration. Finally the cirro-strati appeared in a fan-like form, such as we have seldom seen, ruddy with a still lighter color, which approached orange yellow and forming near the point of convergence where they were intercepted by the clouds which occupied the eastern horizon an arch the vertex of which was exactly at the east-southeast point.

This obliged us to immediately send to the newspapers of the capital that all might know of the terrible enemy that was so near.

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[1] The trajectory of this typhoon may be seen on Plate XXIV (No. 1), Chapter X of Part I.

Typhoon of October 2 and 3, 1894.—On October 2 and 3, 1894, there crossed the center of the Island of Luzon a typhoon of great intensity which after having moved toward the twentieth parallel of north latitude in a west-northwestern direction immediately inclined towards the north, penetrating the continent near Hongkong and Macao, where it appeared to have been the most intense typhoon experienced since the sadly-famous one of 1874. Well, then, from this Observatory we had a chance to behold a beautiful convergency of cirro-strati toward the northwest, which lasted a comparatively long time on the morning of the 4th of October, appearing again at 6 o'clock p. m. The vortex of the cyclone lay then precisely in the China Sea at the northwest of Manila.

Important notice.—We close this chapter with the remark that the direction of the striæ of cirrus or cirro-status (tracto-cirrus of Poëy) must not be confounded with the direction of the cirri themselves. Again, the direction is not the same thing as the convergence of cirrus. The point of convergence specifies the direction of the cirrus belts, but a single stria may have a direction with regard to the meridian of the point of observation, so that it is better to determine its direction when it is near the zenith. The point of convergence of cirri indicates approximately the position of the vortex of the cyclone as has already been shown, and the direction of a single stria or belt will indicate, in the Tropics, either that the cyclonic center exists in one of the two points which the stria marks or that the stria belongs to a system of parallel striæ, in which case the relation between the striæ and the position of the vortex is also determined.

The relation between the movements of the higher strata of the atmosphere, as manifested by the corresponding clouds, and the general course of cyclonic storms is very striking and is clearly brought out by Plates XXX to XXXIII (see next chapter). For the present we content ourselves with pointing out this fact without drawing any conclusions therefrom regarding the causes of typhoon trajectories.

WORKS WHICH MAY BE CONSULTED IN CONNECTION WITH CHAPTER I.

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CHAPTER II. INDICATIONS OF CYCLONES GIVEN BY CLOUDS.

The mean altitude of the clouds—Their normal direction.—The movements of a cloud being dependent upon the movements of the stratum of air in which it floats, cloud motions are the most convenient and at very great heights the only practical means of studying the currents prevailing in the different layers of the atmosphere. We can measure the height of a given cloud above ground with considerable accuracy; we can determine its direction and linear velocity and thus obtain the air current at the level of the cloud. If, moreover, it could be shown that at a given place of observation certain forms of clouds are indicative of certain heights the problem would be greatly simplified; supposing different cloud forms to occupy portions of the sky, a glance at their directions would give us the bearings of the air currents at, let us say, 1,000, 5,000, 7,000, or 10,000 meters altitude. The normal movements of the atmosphere being known, any abnormal direction would warn us of the existence of an atmospheric disturbance. Modern cloud observations, especially the great work of international cloud measurement (1896–97), have shown that the various types of clouds correspond to well-defined zones and the mean altitude of each type at the different stations has been ascertained with all desirable precision. Since we are chiefly treating of the cyclones of the Far East the values of these elements at Manila are of vital importance. To derive them we have employed all the observations made at Manila from 1890 to 1897, inclusive.[1] The practical results of this investigation we exhibit in the following tables which can not fail to be of great practical use in determining the existence, position, and direction of the vortex of a cyclone by means of the cloud directions:

MEAN ALTITUDE OF THE CLOUDS AT MANILA.

[Expressed in meters in the individual months and groups of months.]

Month.	Upper clouds.	Intermediate clouds.	Lower clouds.
January[1]	10,071	5,245	1,805
February	12,584	7,037	1,184
March	11,842	5,913	2,051
April	10,063	5,372	1,846
May	10,526	6,313	1,598
June	13,311	6,546	1,519
July	10,897	6,663	1,440
August	12,210	6,255	2,083
September	11,509	5,080	1,680
October	11,419	4,803	1,641
November	8,641	3,818	1,629
December	10,140	4,501	1,808
Mean	11,098	5,629	1,745
Group I[2]	11,150	5,674	1,877
Group II	10,162	5,077	1,678
Group III	11,982	6,136	1,680

[1] "Las Nubes en el Archipiélago Filipino." Manila, 1899. Table I*a*, p. 30.
[2] "Las Nubes en el Archipiélago Filipino." Manila, 1899. Table I*c*, p. 30. The tabular values given here are $= \frac{1}{2}(Z_1+Z_2)$.

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[1] Two works on cloud measurement have recently been published, forming part of the international system of measurements of the year 1896–97: "Observationes et Mesures de la Suède," Upsala, 1899; and the work of the author, "Las Nubes en el Archipiélago Filipino," Manila, 1898. The tables are taken from the latter work, while the data of the former are given for the sake of comparison.

MEAN ALTITUDE OF THE CLOUD FORMS.[1]

[Expressed in meters.]

Forms of cloud.	April to September.		September to March.	
	Manila.	Upsala.	Manila.	Upsala.
Cirrus	11,133	8,176	10,634	6,980
Cirro-stratus	12,968	6,362	11,638	5,455
Cirro-cumulus	6,823	6,457	6,421	6,131
Alto-stratus	4,302	2,774		4,090
Alto-cumulus	5,707	3,432	4,638	4,114
Strato-cumulus	1,901	1,771	2,322	1,964
Nimbus	1,382	1,197	1,488	897
Cumulus	1,836	1,685	1,821	1,649
Cumulo-nimbus	6,454	[2] 3,971	3,136	[3] 5,175
Stratus	1,065			506

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[1] "Las Nubes, etc.," Table II*b*, p. 31. [2] Summit. [3] Base, 1,378.

MAXIMUM AND MINIMUM ALTITUDES OF CLOUDS AT MANILA.[1]

[Expressed in meters.]

Month.	Cirrus.		Cirro-stratus.		Cirro-cumulus.		Alto-stratus.		Alto-cumulus.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
January	17,449	5,532	10,211	9,789	6,074	5,854			3,988	3,744
February	15,498	8,750	16,233	9,826	7,712	6,200				
March	15,868	6,573	16,488	7,689					7,527	3,169
April	14,128	5,112			7,278	3,249				
May	12,469	5,823	11,682	7,477	6,448	3,448			3,778	3,716
June	20,454	6,412	17,137	10,519	11,225	6,043			5,233	3,973
July	18,014	7,021	14,575	7,112	9,361	4,119	7,086	3,272	7,640	5,000
August	12,855	9,846	16,833	11,367	8,609	4,714	7,141	3,213	7,645	3,874
September	14,871	8,267	15,814		8,293	3,867	5,244	4,274	8,045	2,909
October	16,342	5,764			9,170	3,413	3,898		6,594	3,805
November	12,026	3,962	13,139	9,102	9,564	6,295			5,721	3,758
December	15,786	5,733	14,787	6,879	5,482	4,980			5,600	3,492
Year	20,454	3,962	17,137	6,879	11,225	3,249	7,141	3,213	8,045	2,909

Month.	Strato-cumulus.		Nimbus.		Cumulus.		Cumulo-nimbus.		Stratus.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
January	2,247	2,134	1,951	1,031	3,484	813				
February	1,462		1,620	1,512	3,140	1,014				
March			2,048	1,382	3,821	1,146	10,135	7,592		
April	1,881	1,385			2,793	1,265	6,798	2,976		
May					2,741	870	9,725	3,011		
June					3,283	799	5,051	886	1,184	949
July	1,876	1,384	923		3,931	529	12,859	2,002	1,401	990
August	3,833	1,451	1,982	945	3,547	1,171	8,782	4,559	1,581	612
September	2,194	1,338	1,724		4,449	843	7,751	1,425	1,357	588
October	1,409		989	836	2,742	1,414	7,274	2,043		
November	3,014	2,502	2,294	1,410	2,504	622	6,360	1,140		
December	2,255		1,877	1,504	2,919	1,070	4,779	3,286		
Year	3,833	1,338	2,294	836	4,449	529	12,859	886	1,581	588

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[1] Table IV, "Las Nubes en el Archipiélago Filipino," p. 32.

THE GENERAL CIRCULATION OF THE ATMOSPHERE IN MANILA

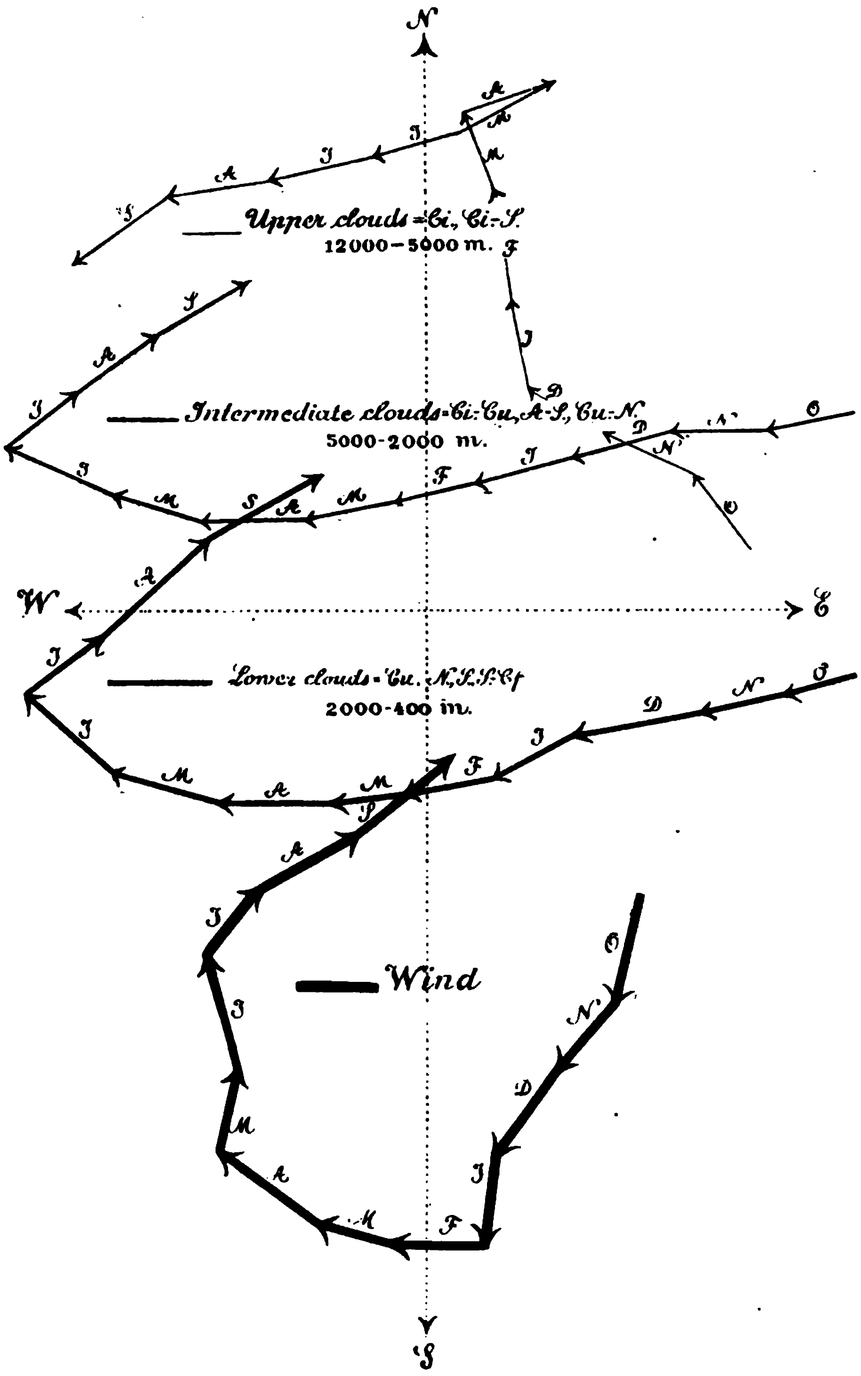

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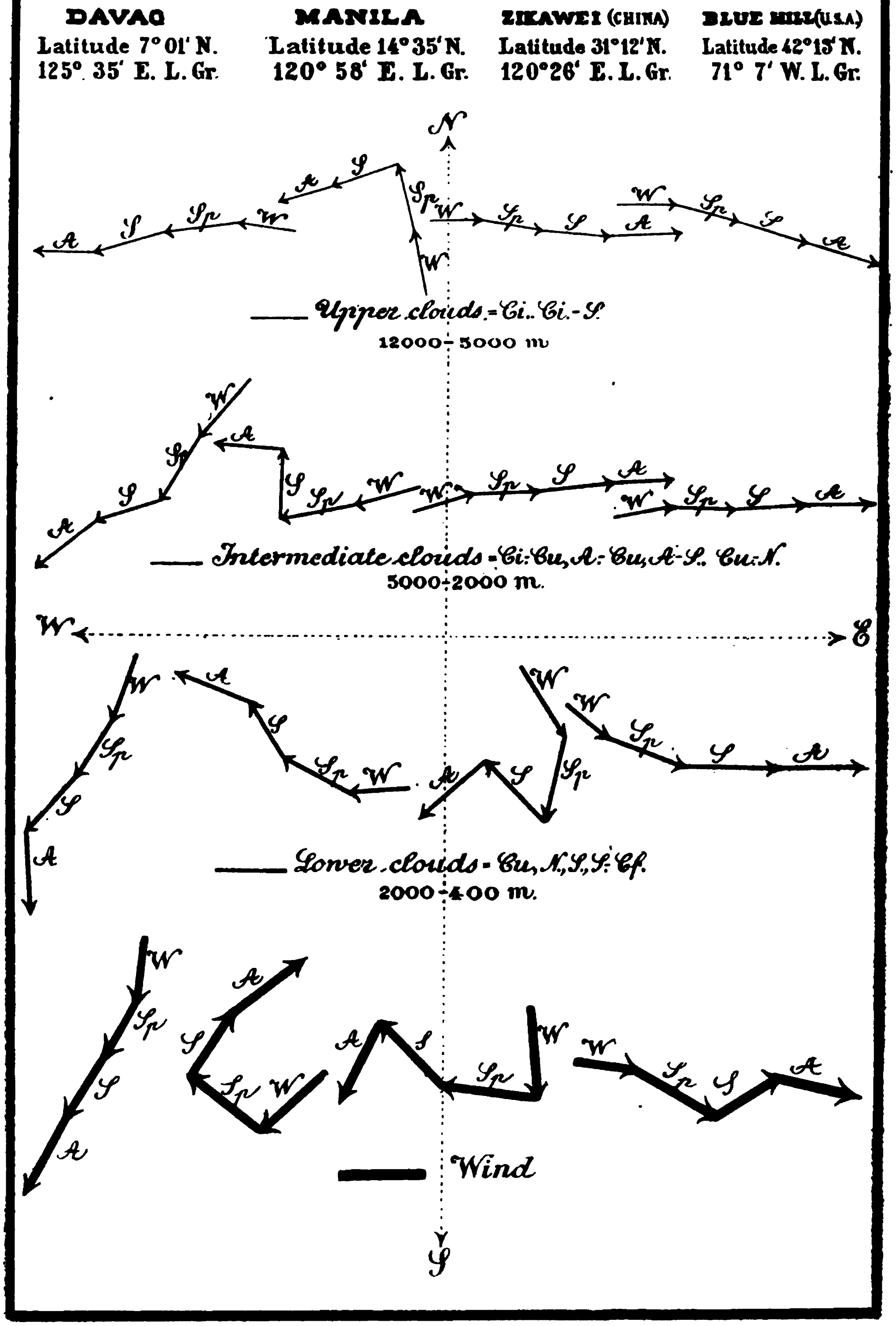
Plate XXXI.

GENERAL CIRCULATION OF THE ATMOSPHERE IN DIFFERENT LATITUDES



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The direction of motion of the clouds in each month.—The direction of motion of the clouds has been calculated for each month, and in order to compare the movements which take place from the surface of the sea up to the highest cloud level, we add a table of the prevalent wind directions:

GENERAL CIRCULATION OF THE ATMOSPHERE AT MANILA.

[Latitude 14° 34′ 41″.]

Month.	Upper clouds.	Intermediate clouds.	Lower clouds.	Wind.
January	S. 6° 0′ E.	N. 79° 34′ E.	N. 76° 59′ E.	N. 5° 39′ E.
February	S. 11° 20′ E.	N. 78° 4′ E.	N. 80° 8′ E.	N. 87° 22′ E.
March	S. 17° 29′ E.	N. 83° 18′ E.	N. 87° 4′ E.	S. 77° 0′ E.
April	S. 82° 54′ W.	N. 86° 25′ E.	N. 88° 40′ E.	S. 51° 36′ E.
May	N. 73° 29′ E.	S. 78° 59′ E.	S. 71° 32′ E.	S. 14° 55′ W.
June	N. 75° 23′ E.	S. 61° 15′ E.	S. 40° 9′ E.	S. 25° 12′ E.
July	N. 76° 28′ E.	S. 54° 58′ W.	S. 54° 15′ W.	S. 46° 51′ W.
August	N. 83° 53′ E.	S. 53° 45′ W.	S. 55° 38′ W.	S. 51° 29′ W.
September	N. 62° 58′ E.	S. 66° 7′ W.	S. 69° 26′ W.	S. 49° 13′ W.
October	S. 47° 25′ E.	N. 77° 36′ E.	N. 74° 25′ E.	N. 14° 5′ E.
November	S. 68° 44′ E.	S. 89° 4′ E.	N. 82° 49′ E.	N. 38° 57′ E.
December	S. 55° 29′ E.	N. 85° 20′ E.	N. 82° 10′ E.	N. 31° 51′ E.

Although the values given refer in the first instance to Manila, we may take them as normal for at least the central portion of the Archipelago. For greater convenience we have plotted graphically the mean directions of the cloud motion (Pl. XXX). The diagram begins with October and ends with September; the directions are referred to the dotted lines of orientation.

The difference, from March to April, in the direction of motion of the high clouds is remarkable, and the more so because neither in April, as in May, June, July, August, or September, does false cirrus often appear nor do cyclones pass over the northern part of the China Sea, which might deceive us as to the true motion of the cirrus.

For the further convenience of observers we also give in the form of a table the resultants of the wind directions for each of the three groups of months:

Group.	Upper clouds.	Intermediate clouds.	Lower clouds.	Wind.
Group I	S. 4° 51′ E.	N. 73° 28′ E.	N. 83° 51′ E.	N. 60° 47′ E.
Group II	N. 82° 28′ E.	S. 80° 44′ E.	S. 76° 56′ E.	S. 1° 16′ E.
Group III	N. 74° 41′ E.	S. 37° 51′ W.	S. 46° 23′ W.	S. 51° 58′ W.

For the sake of comparison we have further given on Plate XXXI a graphical representation of the general movements of the atmosphere at three places in different parts of the northern hemisphere, viz, at Davao, Zikawei, and Blue Hill. It is remarkable that the drifts of the upper and intermediate clouds in Jamaica and at Manila hardly differ from each other, but that the drift of the lower clouds exhibits a somewhat greater difference, which is doubtless attributable to the disturbances of the atmosphere. The drift of the upper clouds at Davao is directly opposite to those at Blue Hill and Zikawei.[1]

The drifts at Zikawei and Blue Hill have been taken from a work by Rev. M. Deschevrens, S. J., "Mouvements des Diverses Couches de l'Atmosphére," Rome, 1896. The drift of the upper clouds at Manila is always easterly, but that of higher latitudes is westerly. While the sun is over the southern hemisphere, i. e., from October to March, the cirrus comes from the second, but in the other months from the first quadrant (Pl. XXXI). We confine ourselves to these data, as it is not to our purpose to investigate here the causes which bring about the atmospheric circulation in the different parallels of latitude.

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[1] "Las Nubes en el Archipiélago," p. 56. See also "Clouds and Cloud Drift in Jamaica," by Hall, 1896.

High clouds—Cirrus, cirro-stratus.—The cirrus rises from the center of the cyclone and at times exhibits a tree-like structure, at other times it is feathery. The direction of the cirrus streaks, and their radiant point especially, are admirable indications of atmospheric disturbances. If there is any probability that the cirri and cirro-strati have their origin in a cyclone, this probability will increase with more careful observation. If they proceed from a radiant point, that will be the position of the center of the cyclone, and we may feel more convinced of this if the direction is not the normal one; if it should be normal the observer must be careful.

It sometimes happens that the direction of the cirri does not correspond with the position of the radiant point. This may arise either from an optical deception in the fixing of the radiant point, or from the energy of the cyclone, or from the different effect of the earth's rotation upon streaks of cirri at different distances from the vortex, or, what is the commoner case, from the fact that the observed direction of the cirri is the resultant of the directions of the normal air current of the higher strata and that which carries the cirri radiating from the cyclonic vortex. These irregularities in the relation of the direction of the cyclonic cirri to the position of the center are generally observed when the cyclone lies to the west of the observer; for then the direction of the cyclonic cirri differs greatly from that of the normal cirri. The graphical representation of the general circulation of the atmosphere at Manila confirms this.

Under favorable circumstances the position of the center may be determined by the form and direction of the cirri at a distance of over 500 miles.

We could give a great number of instances to show the great utility to be derived from convergent cirri as signs of a cyclone. A few of those which came under our personal observation we will give in Chapter III. At present we content ourselves with adducing one case observed outside the Philippine Islands by way of confirmation of our statements. We quote the narration of an eyewitness as published in "Observaciones Meteorológicas hechos en el Colegio Máximo de la Compañía de Jesús en Oña (Burgos)," 1895, page 9 et seq.:

> I do not believe that, with the single exception of telegraphic transmission of information, there is anything in modern meteorology which gives earlier and trustworthier warnings of impending changes of the weather than a constant and intelligent observation of cloud directions. The clouds are more free in their movements and less affected by mountains than the winds in the lower layers of the atmosphere; and often they reveal, by the direction of their motions, the influence of an area of low pressure and its bearing at a time when the barometer neither by its height nor by abnormal daily variation gives any indication of the existence of a cyclonic center.
>
> For this reason several meteorologists have for a number of years given their attention to the study of cloud directions and have published interesting papers on the subject. We mention only M. H. Hildebrandsson's valuable little work, "Sur la Distribution des Eléments Météorologiques autour des Minima et des Maxima Barometriques," Upsala, 1883. As to Fr. Viñes I can testify as witness for years, which I spent at his side, that cloud directions played no small part in making his surprisingly accurate weather forecasts, that were so well known in Cuba and so highly esteemed in the United States by the most competent authorities.
>
> In proof of my assertion I give one out of many cases recorded in my notebook. On Saturday, September 13, 1884, there was at Havana apparently no indication of a suspicious character when the practiced eye of Fr. Viñes discovered that far away a typhoon was crossing the seas in a direction toward the North American Continent. The height of the barometer was normal. At 12 o'clock noon a few cirro-strati came from the northeast, the cumuli or lower clouds from northeast by north, the wind blew from north by northeast. Nevertheless I observed that Fr. Viñes watched the clouds even more carefully than usually and noted their directions very accurately. About 6 p. m. there appeared in the north slightly elevated above the horizon other clouds belonging to the lower types. Having quickly ascertained their direction he called me to his side and said: "Do you see those clouds? Ever since this morning I have expected them; they come from the northwest. Their sight convinces me that there is a cyclone to the northeast which moves toward the United States." Forthwith he sent a dispatch to Washington announcing that a cyclone was moving to the northward of the Bahamas, in the direction of the Gulf of Charleston.
>
> The following day the indications of a typhoon derived from cloud observations were much clearer. The cirri came from northeast by north, the cirro-cumuli from north by northeast, the low cumuli from northwest by north, and the wind from northwest. The gradual change in direction of the air currents thus showed very clearly the influence of the whirl whose center was in the direction from which the cirri came. As for me, I became fully convinced of both the value of cloud directions and the consummate skill of Fr. Viñes in interpreting them, when several days later the weather maps for the 13th and 14th arrived from Washington and I saw how the isobars clearly marked the depression announced by Fr. Viñes.

We do not believe that the direction of the cloud movements is everywhere a sure guide, but only in places where the atmospheric phenomena occur with the greatest regularity—as, for instance, on the Isle of Cuba. Still we are of the opinion that an observer with an experienced eye stationed at a point of the Cantabrian coast with a clear sky and far from the mountains could foretell the storms approaching Spain from the west and northwest with sufficient accuracy to avert the disasters which they are wont to cause.

Few or none of the storms which reach Oña from the west or southwest cross the sea in latitudes lower than the southern part of England and fail to manifest themselves by the movements of clouds before they reach the western coasts of the European Continent.

We think that not only whirlwinds of large dimensions like cyclones might be foreseen but that it would be possible also to predict smaller and local gales—as, for instance, the "galernas" (stiff northeast winds on the coast of Spain).

In general we may assume that we have to do with true cirri, if their direction differs greatly from the normal, and the more so if convergence and other indications confirm the supposition.

Intermediate clouds—Cirro-cumulus, alto-cumulus, alto-stratus, cumulo-nimbus.—The normal motion of these clouds being known, the observer has a useful means at hand to assure himself as to the existence of atmospheric disturbance—that is, if their observed motion is concordant with that of the convergent cirri—inasmuch as there is no room for any further doubt, because cyclonic movement of these clouds is never noticed unless the locality be already in zone A. Under such circumstances the observer will have other indications available in order to set his doubts at rest, such as the movements of the barometer, which will shortly be mentioned, the movements of the lower clouds, the fine rain, etc.

The clouds which usually appear first when the cyclone is nearing a locality are the cumulonimbi, which are the most prevalent in the outer zone; the movement of these clouds is as various as is the usual movement of such disturbances.

The same may be said also of the false cirri which have already been mentioned and of which we shall treat specially in the next chapter.

The alto-cumulus, cirro-cumulus, and alto-stratus[1] may more properly be counted among the indications.

These clouds, whenever belonging to a cyclonic disturbance, preserve a close and invariable relation to the bearing of the vortex, which connection gives them their great value as precursory signs. Fr. Viñes has brought out these relations in a masterly manner in his laws of cyclonic circulation, which to repeat here there is no necessity.

Lower clouds—Cumulus, nimbus, stratus, cumulo-stratus.—Among this group of lower clouds we class the fracto-cumulus, fracto-nimbus, and the other forms of clouds which are usually very abundant when the cyclonic winds freshen up and which drift with great velocity. As regards the fracto-cumulus, which, as a rule, is usually seen when the station lies in zone A, Fr. Viñes says that it occasionally moves in a direction divergent from the cyclonic center. Hence the indications given by this type must be received with great caution when they do not agree with the observations of the other phenomena. We have already described in Chapter III of Part I how the locality of the center may be determined from the movement of the lower clouds.

The direction of the lower clouds affords us the best means of testing the real value of the conclusions drawn from the direction of the wind, for it often happens that although a station is as yet only in zone A, still it is no longer possible to see the intermediate, much less the upper, clouds; but it rarely happens that we can not observe the lower clouds, so that there is always an opportunity for ascertaining the lower currents of the wind.

As a practical rule of general application it may be stated that the indications derived from the directions of the clouds are the less ambiguous the more these directions depart from the normal tracks of the respective cloud forms.

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[1] We wish here to point out that the cirro-strati or the dense cirrus sheet of Fr. Viñes are not the cirro-strati of the international definitions, but Poëy's cirro-strati; however, Viñes differs from Poëy in that he assigns to cirro-stratus a less elevation than to cirro-cumulus, and yet this latter is decidedly classed with the intermediate clouds. Is Viñes' cirro-stratus to be identified with the alto-stratus of the international nomenclature?

Instances taken from practical experience.—From two cases, which we take from the observations of November, 1891, we shall see in what way we are to interpret the indications given by the various cloud forms, so as to follow the movements of the center, and also of what importance it is to take heed of the modifications which the normal upper air currents may introduce into the cyclonic movement.

Two typhoons passed over the south of Luzon between November 12 and 17, 1891, and they were most particularly disastrous, inasmuch as both swept over the richest provinces in the south and southeast of the Islands. The first had a trajectory from east to west and moved with great velocity to Cochin China; the second moved from east-southeast to west-northwest across the provinces to the southward of Manila and ultimately reached the Gulf of Tonkin.

The first crossed the meridian of Manila in the afternoon of the 13th and the second in the morning of the 16th. The center of the first passed the capital at a distance of 70 and the second at that of 50 nautical miles. On the 10th cirri, convergent toward the southeast, were seen and remained visible for five hours, and a convergence toward south was also observed. The convergence to the southeast persisted also on the 11th, when the barometer began to show a tendency to fall. It is remarkable that the center lay to the east-southeast of Manila; at noon on the 11th it was at a distance of 600 miles, if we attribute to it an average velocity of 13 miles an hour. At such a distance the rotation of the earth may have had some influence on the deviation of the cirri, for it was observed that during the 11th they came from south-southeast. On the 12th, when the cyclone was quite close at hand, the cirri came from southeast. On the 13th they were invisible, but the observer already knew that the cyclone was approaching from the second quadrant. On the 11th, in the afternoon, the wind came from directions between north and northeast, the lower clouds from east-northeast, and the cirri from south-southeast. On the 12th, in the afternoon, the cirri came steadily from southeast and the cirro-strati from northeast; on this afternoon the center lay southeast by east from Manila, and the deviation of the cirri was almost nil. At 7 a. m. on the 13th there appeared some lower clouds, under the mass of nimbus, which drifted at a great rate from north-northeast. When these fragments of clouds were coming from north-northeast the nimbus, which was above them, came from northeast, but the wind below was from north or northwest—a splendid confirmation of the laws of cyclonic circulation. The wind and the direction of the clouds drew round to east as the center was passing to the south of Manila, so that in the night of the 13th the wind came from north-northeast, and the lower clouds from east-northeast. On the morning of the 14th the direction of the lower clouds had already got to east-southeast, while the wind held in the east up to noon.

In the afternoon of the 14th an irregularity set in in the shift of the currents; the lower clouds and the wind, which ought to have veered to the southeast, backed and came from east-southeast and east; at the same time the cirro-strati came also from east-southeast, instead of showing the passage of the cyclone, and when night came on they had a decided convergence to south.

The cause of this anomaly was a fresh cyclone, which was at a distance of 500 miles and was advancing toward the capital, so that the directions which were observed were the resultants of the currents coming out of the two cyclones. The wind currents on the 15th were as follows: The upper clouds came from southeast, in which direction an arborescent ramification and a convergence of the cirri appeared; during the whole day the cumulo-strati and cumulo-nimbi came from east-northeast. On the 16th the sky was overcast and there was rain, but at 7 a. m. it could be distinguished that the lowest clouds were coming from north and that others were coming with great velocity from northeast, and later on from northeast and east, from which points the bulk of the rain clouds drifted. Then there appeared at various levels individual clouds moving at a great rate and having a direction intermediate between that of the wind and that of the nimbus.

Besides what has been said in Chapter IX of Part I, it will not lack interest to indicate here the influence which the movement and direction of the upper currents may have on the movement of translation of cyclones. If the height of the body of the cyclone does not reach the height of

Plate XXXII.

GENERAL CIRCULATION OF THE ATMOSPHERE IN THE FAR EAST.

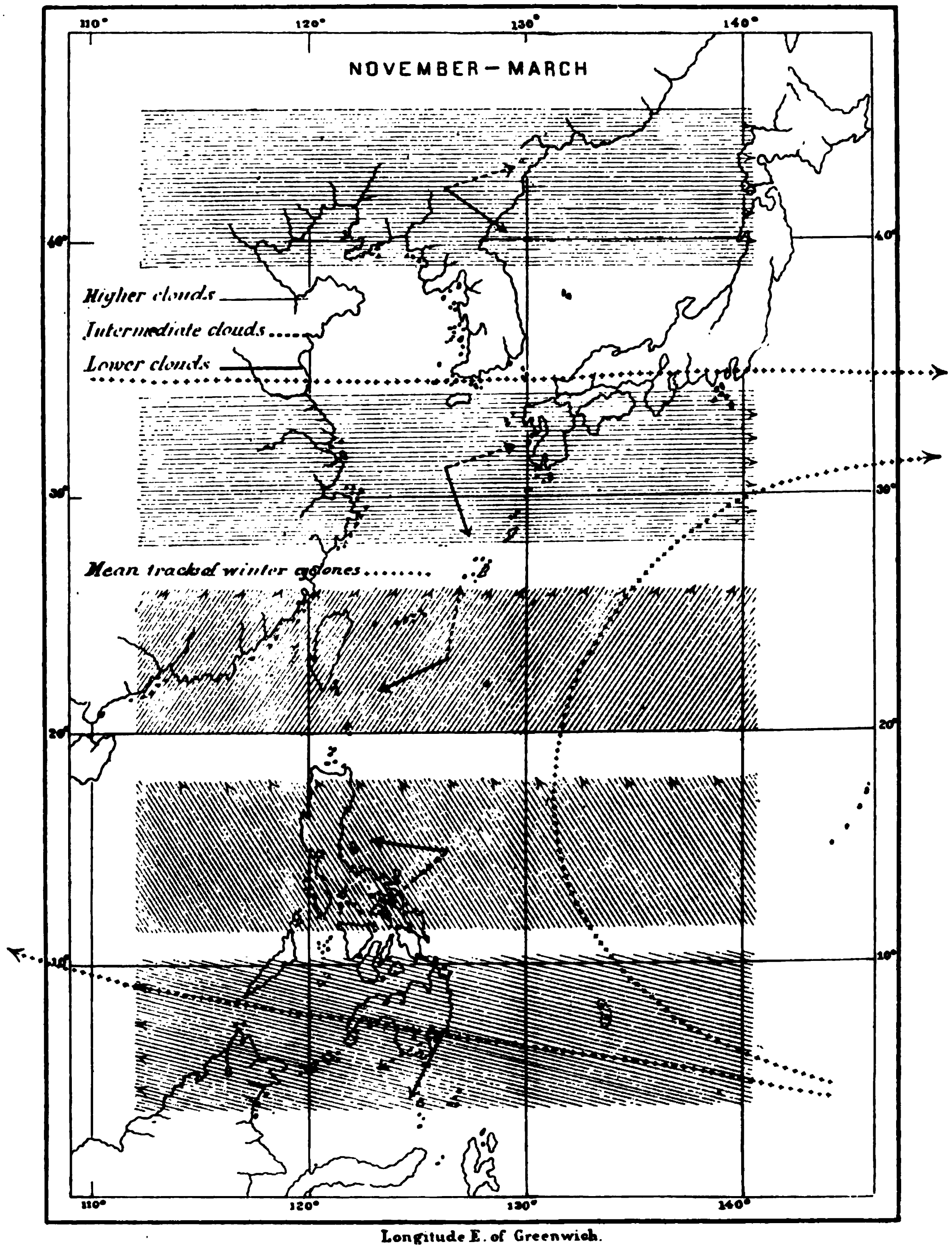

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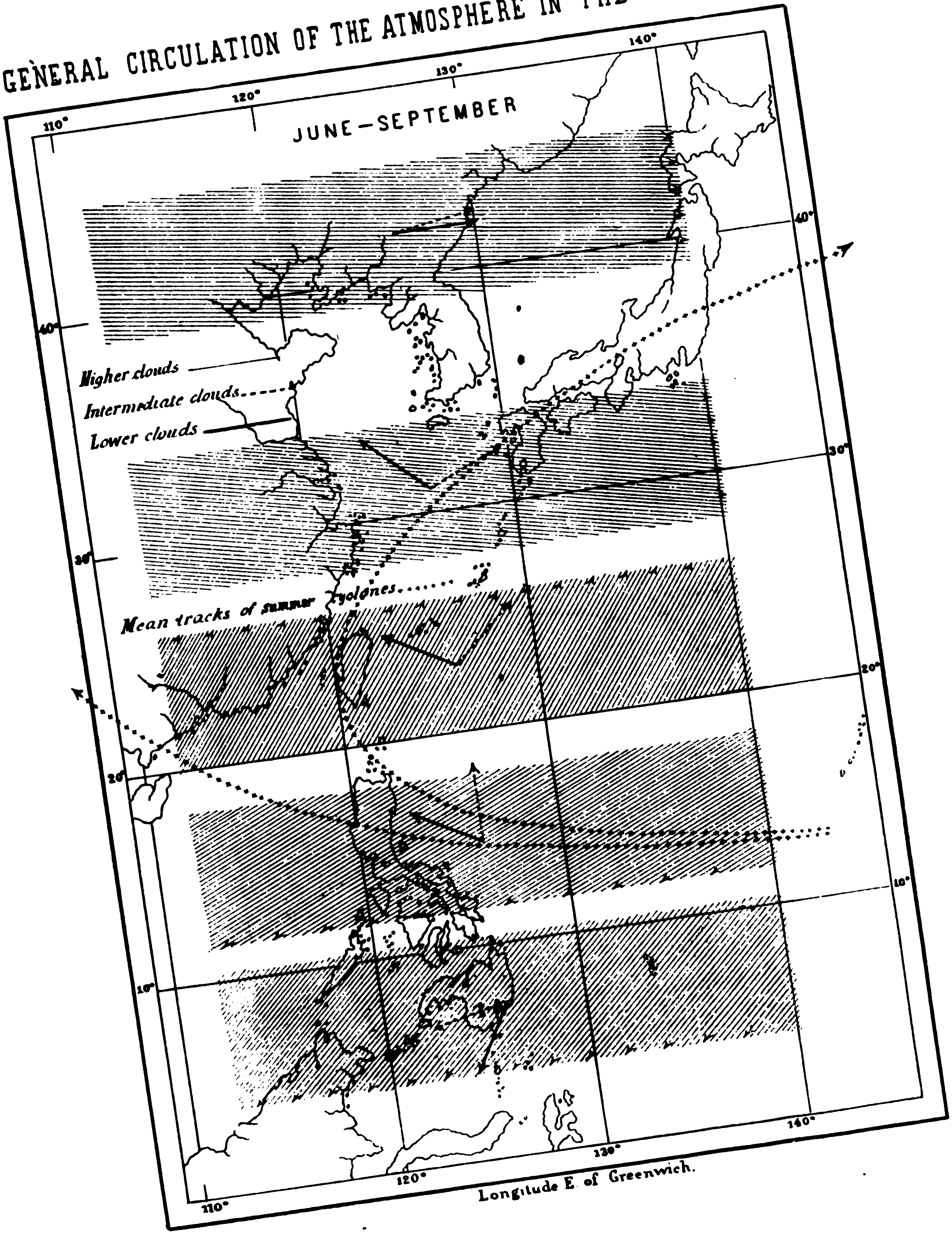
Plate XXXIII.

GENERAL CIRCULATION OF THE ATMOSPHERE IN THE FAR EAST



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the cirro-stratus clouds it will be easy to understand the influence which the movement of these clouds may have on the forward movement of the cyclone. If the emergent cirri rise to the mean region of the cirro-stratus it is probable that the influence of the movement of the clouds will not be altogether neutralized. On Plates XXXII and XXXIII we express graphically the mean direction of the high, intermediate, and low clouds, together with the mean trajectory of the cyclones in winter and summer. The movement of the clouds has been deduced principally from the observations made in Manila, Havana, Zikawei, Blue Hill, and Japan. The coincidence of the general movement of the cyclones in the Pacific with that of the high clouds is very extraordinary, especially from November to March.

Amount of clouds in Manila.[1]—It will not be without interest to give here (Pl. XXXIV) the mean cloudiness of Manila for the different months of the year. In the diagram it runs directly contrary to the variations of temperature and of the hygrometric condition of the air. Amount of clouds: January, 5; February, 4.2; March, 4; April, 3.6; May, 6.3; June, 7; July, 7.6; August, 7.9; September, 8.3; October, 6.2; November, 6.2; December, 5.8, "0" denoting a perfectly clear sky and "10" a sky completely covered with clouds.

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[1] "Las Nubes en el Archipiélago Filipino," pp. 31, 32.

CHAPTER III. PHOTOGRAPHY OF THE CLOUDS AND WEATHER FORECASTING.

Photography of the clouds.—In recent years the altitude of the clouds has been obtained trigonometrically, either by means of direct observations or with greater accuracy by photography. The photographic method was employed in this Observatory from June 1, 1896, with the object of contributing to the great international work of the determination of the general movements of the atmosphere over the whole globe on the basis of precise measurements of the height, direction, and velocity of the clouds.[1] By means of these researches we got together most valuable data concerning the relation which exists between the altitude of the clouds and the great tropical atmospheric disturbances.

Photographic apparatus.—The photographic apparatus employed at the Manila Observatory for the work were two symmetrical photogrammeters of French construction and two German phototheodolites. These instruments may be taken as two types of phototheodolites which are now in use. There is no essential difference betwen the two instruments.

The French photogrammeters (Pl. XXXV).—the photogrammeters constructed by M. Echassoux, mechanic of Teisserenc de Bort, secretary of the Central Meteorological Office of France, are apparatus of very fine workmanship. They consist of two circles, one vertical and the other horizontal, divided to half degrees. By means of the verniers placed at the extremities of a diameter the minutes of arc may be read directly in both directions and the fractions of minutes approximately. As may be seen in the figure the apparatus are fitted with all the modifications introduced in the best theodolites. The special excellence of this instrument lies in the camera obscura and the reticle of the plates. The camera, which turns about the center of the theodolite, consists of three metal boxes firmly fixed together that the focal distance may be always the same and the optic axis of the objective remain unchanged. The shutter of the lens may be worked either by a weak current of electricity or by compressed air. The diaphragms are attached to the shutter itself, and the change from one to the other is made by means of two levers which carry also the index of the diaphragm. The lens slides into another tube to facilitate the process of focusing. When the focus is once found the objective is clamped to the tube by pressure screws. Each apparatus is also provided with two yellow glass screens of different tints which are placed in front of the lens to neutralize the effect of the blue of the sky when the instruments are employed for cloud photography. The reticle is engraved on a slightly yellow glass plate, enclosed in a metal frame and placed very near the sensitive plate. This reticle is adjusted by screws and can be moved from the exterior of the camera. The photogrammeters were constructed for Manila under the direction of M. Teisserenc de Bort at the special request of his colleague, H. H. Hildebrandsson.

The German phototheodolites (Pl. XXXVI).—The phototheodolites constructed by O. Günther, of Braunschweig, are similar to those made by the same for the Central Observatory of Prussia at Potsdam. They possess some characteristic differences from those of Echassoux, some of which are of great importance for the use for which they are primarily intended, which is the measurement of the altitude and direction of the clouds. The lens, of Jena glass, is of the type

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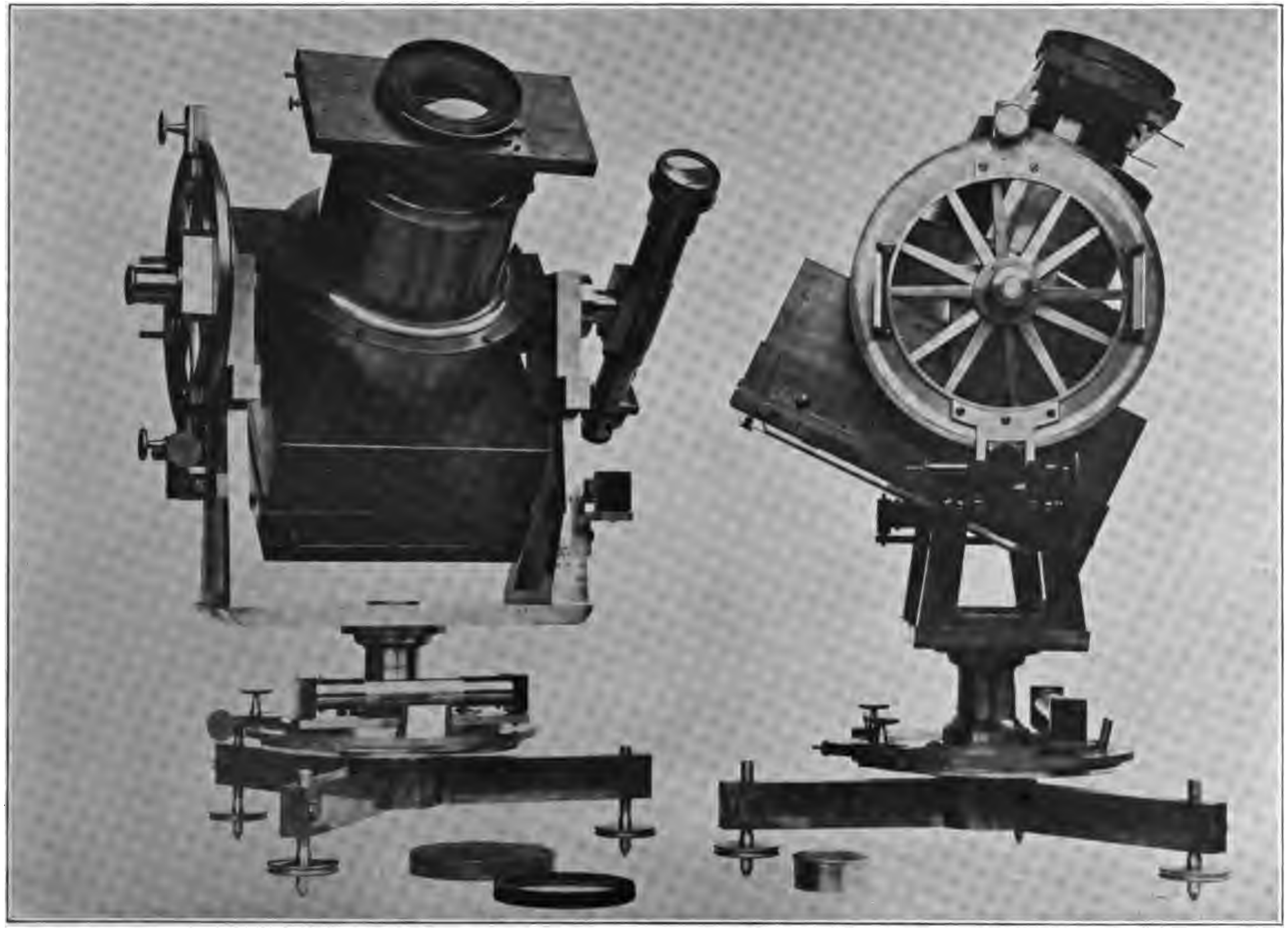
[1] Sixteen observatories took part in this work; Manila was the only one in the Far East.

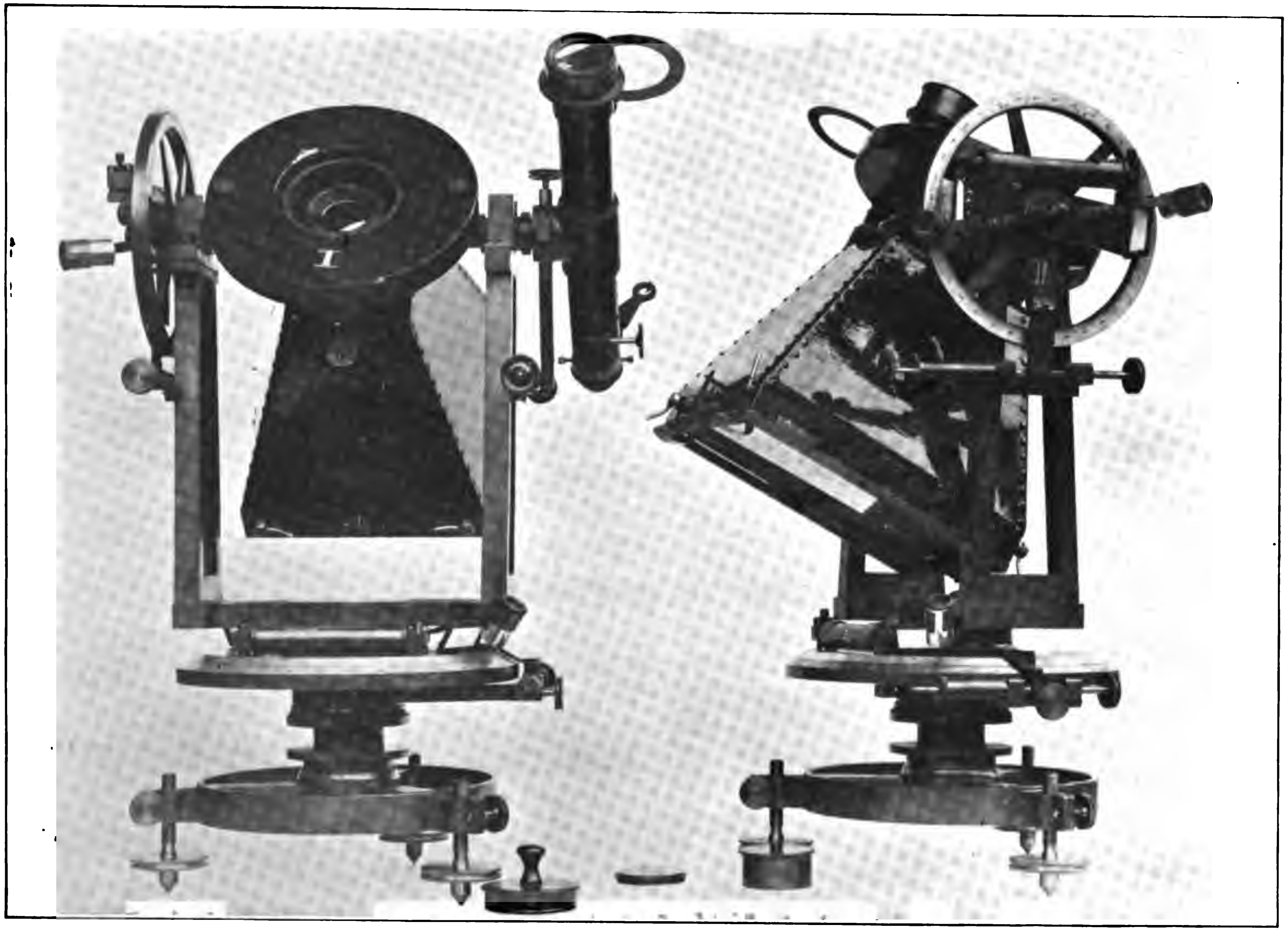
Plate XXXV.



PHOTOGRAMMETERS.

UNIV. OF MICH.

Plate XXXVI.



PHOTOTHEODOLITES.

UNIV. OF MICH.

known as collinear and classified by the maker, Voigtländer, of Braunschweig, as collinear II^{3}; its diameter is 25.5 millimeters and the focal length 154.64 millimeters. This collinear objective consists of two symmetrical systems of lenses separated by an iris diaphragm, as may be seen in fig. 6.

This combination is of great value. as it diminishes the differences of focal distances around the intersection of the optic axis on the plate. Both calculation and experience give the following relation of the distances of the prinicipal points of the two halves from the center of the system with respect to the greater or less inclination of the incident rays to the optic axis:

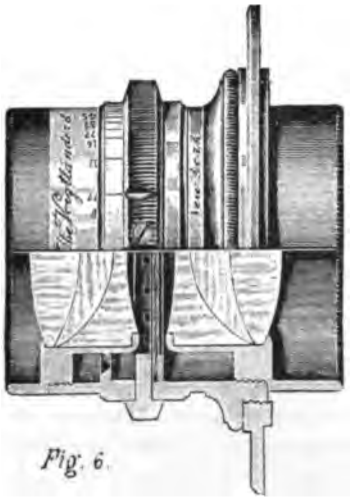


Fig. 6

Inclination of the incident ray to the axis.		Distance of the principal points from the middle of the system of lenses.
°	′	Mm.
0	0	2.51
21	7	2.43
30	34	2.22
35	19	1.97
39	39	1.52

Hence it is deduced that at an angular distance of 40° around the optic axis the focus will be approximately 1 millimeter farther away than for a point situated on the optic axis itself.

The image of these lenses is free from astigmatism. To secure more exactly the constancy of the focal distance the German constructor makes the camera obscura itself serve as plate holder, so that the sentized surface is always at the same distance from the objective. The camera obscura consists of a pyramidal metal box (see Pl. XXXVI.) This apparatus, instead of having a reticulated glass plate like the French instrument, is furnished with four metal arrowheads, so disposed that their points are the extremities of the vertical and horizontal lines of reference, and since the surface of the plate rests upon them they mark upon it these directions. The lines which join the vertices of the arrow heads divide the plate into four parts. The intersection of these lines must correspond to those in the reticle of the telescope which the apparatus carries and to the zero of the vertical circle when the optic axis is horizontal, in order to adjust the instrument for altitudes. For adjustment in azimuth, once the two reticles of the camera and the telescope are made to agree, we have only to proceed in the ordinary way for the adjustment of the common theodolite.

Four stations for this work of measuring the clouds were erected in this Observatory—two situated at the extremities of a base of 1,702 meters and two others on a base of only 243 meters.

As it is of the greatest importance that the exposures be made at both stations at the same instant, the stations with the larger base have been connected by telephone; at the stations occupying the end points of the shorter base the photographic shutters are worked simultaneously by electricity. An examination of the observations showed satisfactory results for both pairs of stations; the errors of observation, etc., were found to be of such nature and quantity that they largely disappeared, thus rendering it possible to ascertain the mean heights of the various types of clouds with great accuracy.

After these preliminaries we propose to show in this chapter three things: (1) The photographic measurements of clouds fully bear out our statements concerning the great importance of cloud directions in weather forecasting; (2) cloud photography provides us with the means of determining the inclination of the axis of cyclones and thus deciding beforehand which side of the cyclone field will probably be the most dangerous; (3) by measuring the altitude and ascertaining the direction in which the cirri move, cloud photography enables us to distinguish true from false cirrus.

(1) **Some examples showing the importance of photographic measurements with regard to weather forecasting.**—The first typhoon which was experienced in Manila after it had become possible to measure the altitude of the clouds photographically crossed the south of Luzon in the vicinity of Batangas on June 6, 1896, and reached the ocean after having caused between Punta Santiago and Punta Restinga more than twenty-five shipwrecks in the inland seas. This cyclone was one of the most violent which visited the Archipelago during that year. On the 4th cloud altitudes were photographically measured; the plates showed a group of symmetric patches corresponding to a streak of cirrus and two groups which belonged to cirro-stratus. The center was more than 500 nautical miles distant, and the barometer showed no symptoms whatever of the existence of a storm field, so that the Observatory was able to report in the newspapers "Barometer rising over the whole island." At 10 o'clock it looked somewhat suspicious, but there was no certain indication, so that the report was "Barometer high, but not very steady; weather uncertain." It was not until the 5th that the approach of the much-feared meteor was recognized, judging from the usual indications of the instruments but especially from the photographic plates taken on the 4th, which showed the cirri that issued from the cyclonic vortex. These measurements not only gave the exact height and direction of these clouds, but also indicated the existence and bearing of the typhoon vortex.

MEASUREMENTS FOR JUNE 4, 1896, 4.35 P. M.

Type of clouds.	Altitude above sea level.	(*x*)	(*y*)	(*d*).	Direction.	Velocity.
	Meters.	*Meters.*	*Meters.*	*Meters.*		
1. Cirrus	12, 300. 8	—12, 500. 0	—16, 418. 1	3:27, 051. 3	SE.	Ordinary.
2. Cirro-stratus	14, 027. 4	—26, 404. 1	—25, 012. 8	3:36, 370. 8	SE.	Do.
3. Cirro-stratus	11, 608. 1	—27, 786. 0	—26, 385. 9	3:31, 820. 7	SE.	Do.

(*x*) and (*y*) are the rectangular coördinates of the projection of the central point of the group, measured above the horizon. The ordinal number in column (*d*) gives the quadrant in which the center of the symmetrical points, of which the group in the cloud consists, projects itself on the horizon. The figure in the same column expresses in meters the distance of the projection from the southern station. The same designations apply to the subsequent tables.

It must be mentioned that a convergence of the cirri toward the east was observed on the 4th, although at this date the center was situated to the southeast of Manila, but if we bear in mind the great distance, this may have been caused by the upper normal air currents which in June come from the east-northeast, in conjunction with the rotation of the earth.

We have another excellent example during the same month. On the 13th and 14th a depression was developed in the south of the China Sea; the cirrus, which was measured at Manila on the 13th, showed the bearing of the center which was then being formed; the cirrus of the 14th indicated a progressive movement of the typhoon which, according to a note issued by the Observatory, was moving away from the Archipelago on the 16th.

MEASUREMENTS FOR JUNE 13 TO 14, 1896.

Day.	Type of clouds.	Altitude above the ocean.	(x)	(y)	(d)	Direction.	Velocity.
		Meters.	*Meters.*	*Meters.*	*Meters.*		
13	1. Cirro-stratus	13,587.7	26,741.2	—29,682.0	4:39,951.0	SW.	Slight.
13	2. Cirro-stratus	10,537.3	34,247.7	—29,579.3	4:45,253.3	SW.	Do.
14	1. Cirrus	12,037.1	11,054.5	— 4,871.8	4:12,080.3	WSW.	Ordinary.
14	2. Cirrus	10,351.9	11,407.7	— 3,868.7	4:12,045.8	WSW.	Do.

Time of observation: On the 13th, 8.53 a. m.; on the 14th, 9.05 a. m.

The directions of the cirri on the 13th and 14th were quite abnormal and indicated a slow progressive motion and an inclination to the north. The cyclone reached, apparently, the Asiatic continent in Tonkin on the 21st.

The month of July of the same year, 1896, furnished further photographic measurements very apropos to confirm what we are trying to establish. On July 25 cirro-cumuli were measured which had an altitude of more than 8 kilometers, and their direction, east-northeast, showed undoubtedly the existence of a typhoon. It crossed the extreme northeast of Luzon three days later, and was marked by a very low barometer, the reading being as low as 716 millimeters at Aparri. As may be seen in the following table, the masses of cirri came on the 27th from north-northeast, the seat of the center, which passed near Aparri at noon on the 28. The notice issued by the Observatory on the 28th reads as follows: "Barometer very low, but shows a tendency to rise; the storm field has reached the island this morning in the Province of Cagayan and is of great intensity."

The strato-cumulus observed in the fourth quadrant on the 29th came from south-southwest, the center being at the time to the northwest of Manila. This gives another proof of the fact that the direction of the winds as well as that of the clouds in the rear of a cyclone are convergent.

MEASUREMENTS FOR JULY, 1896.

Day.	Type of clouds.	Altitude above the ocean.	(x)	(y)	(d)	Direction.	Velocity.
		Meters.	*Meters.*	*Meters.*	*Meters.*		
25	1. Cirro-cumulus	8,587.5	23,436.8	12,521.1	1:26,568.8	ENE.	Ordinary.
27	1. Cirro-cumulus	5,288.3	— 7,410.5	3,359.0	2:8,136.4	NNE.	Do.
27	2. Cirro-cumulus	5,021.5	— 7,441.2	4,348.2	2:8,618.4	NNE.	Do.
29	1. Strato-cumulus	1,875.7	— 807.9	8,335.1	2:8,374.2	SSW.	Do.
29	2. Strato-cumulus	1,536.7	247.0	6,486.1	1:6,491.0	SSW.	Do.

Time of observation: On the 25th, 11.29 a. m.; on the 27th, 5.21 p. m.; and on the 29th, 9.30 a. m.

This typhoon crossed the China Sea rapidly, striking Hongkong, where it caused such an amount of damage as had not been experienced since the noted typhoon of 1874.

The month of October, 1896, furnished likewise some cloud measurements well calculated to show the great importance of an exact knowledge of the heights and directions of the clouds in order to foretell and study atmospheric changes. In order to avoid prolixity we shall limit ourselves to a few instances. In the morning of October 4, 1896, a typical cyclone crossed the Island of Luzon. It entered toward the south of Isabela and passed out into the China Sea south of Vigan, traversing the Province of Ilocos Sur almost exactly in the middle. On the 2d two groups of cirro-cumulus were measured at Manila and one group of alto-cumulus. As all three came from northeast, traveling at the regular rate, they created a suspicion that a cyclonic center was approximately to the east-northeast of Manila. But the barometer was rising, and consequently there were as yet no other indications of the typhoon than the cloud measurements. On the morning of the 3d the barometers began to vary, so that at 10 a. m. it was possible to issue the warning: "The barometers are falling again, and there is a depression in the east-northeast over the Pacific; direction of the wind, from the northwest quadrant." This typhoon reached the "Celestial Empire" at a short distance to the north of the Island of Hainan. We give the results of the photographic measurements in the following table.

When the above-mentioned typhoon was crossing Luzon on the 4th, another one of no less violence was forming to the east of the Mariana Islands. The presence of this new cyclone was also detected by the state of the clouds. On the morning of the 7th four groups of cirro-cumulus were measured, which were traveling slowly from the east-northeast and whose altitudes were found to be very small for this type of clouds (for reasons which will soon be explained); facts which evidently pointed to the existence of a center of disturbance toward the east or east-southeast.

The typhoon reached the shore to the north and near Casiguran, striking the China Sea to the south of Vigan. When it was moving off from the Archipelago on the 10th a convergence of cirrus clouds was noticed in the northwest; they were formed at the rear of the cyclone by the highest wind currents, and their altitude, as may be seen in the following table, was over 15,000 meters.

This typhoon, when in the China Sea, recurved toward the Formosa Channel, as may be deduced from the observations made on board the French cruiser *Isly,* which on the 10th was between Formosa and the northeast coast of Luzon, bound for Manila.

MEASUREMENTS FOR OCTOBER, 1896.

Day.	Type of clouds.	Altitude above the ocean.	(*x*)	(*y*)	(*d*)	Direction.	Velocity.
		Meters.	*Meters.*	*Meters.*	*Meters.*		
2	1. Cirro-cumulus	6, 349. 1	—10, 746. 2	4, 014. 4	2:11, 471. 8	NE.	Ordinary.
2	2. Cirro-cumulus	5, 260. 1	—10, 917. 0	6, 883. 7	2:12, 905. 9	NE.	Do.
2	4. Alto-cumulus	3, 804. 8	—10, 499. 8	6, 478. 9	2:12, 335. 6	NE.	Do.
7	1. Cirro-cumulus	4, 817. 9	— 546. 6	9, 266. 0	2: 9, 283. 0	ENE.	Slight.
7	2. Cirro-cumulus	4, 340. 0	671. 1	11, 396. 3	1:11, 396. 3	ENE.	Do.
7	3. Cirro-cumulus	3, 325. 6	— 846. 4	12, 459. 6	2:12, 488. 0	ENE.	Do.
7	4. Cirro-cumulus	3, 333. 3	— 470. 2	16, 587. 5	2:16, 594. 2	ENE.	Do.
10	Cirrus	15, 338. 4	2, 959. 2	33, 654. 9	1:16, 594. 2	NW.	Ordinary.

Time of measurements: On the 2d, 9.55 a. m.; on the 7th, 8.42 a. m.; on the 10th, 11.37 a. m.

The last decade of June and also of July, 1897, was each characterized by great atmospheric activity, and they were therefore especially adapted to show that we are not only enabled to fix the altitude and direction of the clouds of a single cyclone by the photographic method, but that we are also justified in drawing from the cloud pictures conclusions as to the existence, the place, and the character of several centers of typhoons which may appear simultaneously.

At 4 o'clock in the afternoon on June 19 two cyclones existed simultaneously, making their influence felt in the Archipelago; one of these was over the Pacific, northeast of Manila, the other almost due west over the China Sea. The photographic observations of the 19th give us information as to the altitude and the direction of the cirrus radiating from the Pacific center. On the 20th at 4 p. m. the China Sea center was already nearly opposite Cape Bojeador, northwest by north of Manila, but the Pacific center had made but little headway in latitude and lay at the time off the Bashi Channel, almost to the northeast by north of Manila. If we examine the cloud measurements of the 20th we shall find that the group of the cumuli belonged to the China Sea typhoon, the group of the cirri, however, to the Pacific center. It is very noteworthy that the cirri of the 20th were almost twice as elevated as those of the 19th—they indicate the progressive movements by their changes of direction, and the change in position of the axis of the storm field by their changes in altitude. On the 21st the China Sea typhoon was approaching the south of Formosa;

the Pacific cyclone was advancing toward Japan, and at 4 p. m. it was already more than 900 nautical miles distant from Manila. The cumuli, which were measured at 9 a. m. on the 21st, belong to the China Sea typhoon, which was at the time about 300 miles distant from Manila. This center was almost stationary on the 21st and 22d, so that the cumulus and nimbus had hardly altered their direction.

The photographs were made on the 19th at 11.15 a. m., one the 20th at 8.54 a. m., on the 21st at 9.30 a. m., on the 22d at 11.40 a. m.; on the 26th at 9 a. m., on the 29th at 10.46 a. m.

MEASUREMENTS FOR JUNE, 1897.

Day.	Type of clouds.	Altitude above the ocean.	(*x*)	(*y*)	(*d*)	Direction.	Velocity per second.
		Meters.	*Meters.*	*Meters.*	*Meters.*		*Meters.*
19	2. Cirrus	9,392.3	932.0	19,404.3	1: 19,426.8	N. 50° 23′ E.	10.95
19	3. Cirrus	9,585.3	3,937.2	21,312.4	1: 21,673.0	N. 50° 23′ E.	10.95
20	1. Cirrus	18,527.9	—24,997.0	52,212.2	2: 57,887.1	N. 29° 22′ E.	13.22
20	2. Cumulus	1,527.9	— 2,196.9	5,689.0	2: 6,097.9	S. 20° 31′ W.	10.19
21	2. Cumulus	1,076.0	— 1,341.2	1,908.3	2: 2,332.6	S. 51° 09′ W.	1.51
22	1. Cumulus	2,767.9	— 3,018.0	6,229.0	2: 6,229.0	S. 30° 26′ W.	9.10
22	2. Nimbus	1,933.6	— 3,339.2	5,248.3	2: 6,220.6	S. 30° 26′ W.	9.10
26	1. Cirrus	13,333.3	10,617.0	17,634.8	1: 20,583.8	N. 88° 11′ W.	14.05
26	2. Cirrus	20,452.3	20,165.9	31,052.9	1: 37,026.4	NNE.	14.05
29	1. Cirrus	14,110.8	—17,133.2	9,985.3	2: 19,830.9	N. 65° 42′ E.	12.80
29	2. Cirro-stratus	17,136.8	—21,856.0	22,897.3	4: 31,654.3	N. 65° 42′ E.	12.80

The coexistence of two depressions for so long a time was a very favorable circumstance for the formation of parallel cirrus belts; they appeared, therefore, on the 20th, with the direction of the belts running from west-southwest to east-northeast, and on the 22d from south-southwest to north-northeast. This confirms what has already been said about these belts, although in these cases they were not normal to the line joining the two centers, though they lay between them.

We have to draw special attention to the photographic observations of the 26th. There were at that time two upper air currents over Manila which were very distinct from each other; the one at an altitude of more than 20 kilometers came from north-northeast, and therefore from a direction in which a depression existed at a great distance; the other had its origin in a cyclone in an almost westerly direction, which made itself felt on the south coast of China and in the China Sea. This depression was so far distant that no other indication of it appeared at Manila, unless we accept as such the cirrus belts which ran from north by northeast to south by southwest on the 25th.

In the afternoon of the 29th there appeared to the northeast of Manila over the Pacific a new center, the pressure of which was revealed through the photographs of the cirri and cirro-strati which were moving at a rate of only 12 meters per second from the northeast by east; on July 2 the cirri came almost from the north, and we found that the cyclone at this time was already crossing the south of Formosa.

The last decade of July, 1897, was not less characterized by cyclonic activity. Three cyclones made their influence felt in the Archipelago on the 23d; one of these lay over the Pacific northeast by east of Manila; the second lay to the southwest by west; and finally the third to the northwest.

Of the photographs taken on the 23d and 24th, the cirri observed on the morning of the 23d belong to the Pacific cyclone, the cirro-cumuli and the cumuli, however, to the center situated to the northwest. The influence of the latter made itself felt during the early morning of the 24th on board the Spanish cruiser *Cristina*, then on her voyage from Hongkong to Manila. The observations made by the captain of the vessel, Don Luis Cadarso, were kindly placed by him at the disposal of the Observatory. The cirrus measured on the 24th originated likewise in the Pacific cyclone; the cumulus, however, without any doubt came from the center which was to the west of Manila on the 25th.

The photographs were taken on the 2d at 3.54 p. m., on the 23d at 10.57 a. m., and on the 24th at 11.37 a. m.

MEASUREMENTS FOR JULY, 1897.

Day.	Type of clouds.	Altitude above the ocean.	(x)	(y)	(d)	Direction.	Velocity per second.
		Meters.	*Meters.*	*Meters.*	*Meters.*		*Meters.*
2	2. Cirrus	7,021.4	11,271.0	9,485.0	1:14,731.3	N. 7° 34′ E.	42.13
2	3. Cirrus	12,314.3	25,777.7	18,596.1	1:31,879.3	N. 7° 34′ E.	42.13
23	1. Cirrus	8,715.1	1,123.8	19,179.1	2:19,211.8	N. 54° 13′ E.	9.14
23	2. Cirro-Cumulus	4,429.4	408.5	10,553.2	2:10,561.2	S. 64° 20′ W.	37.87
23	3. Cumulus	1,045.9	206.2	2,700.6	1: 2,708.4	S. 15° 41′ W.	1.29
24	1. Cirrus	12,345.7	7,314.8	17,415.2	1:18,889.1	N. 59° 25′ E.	10.58
24	2. Cirrus	11,397.5	4,657.6	22,294.7	1:22,776.2	N. 59° 25′ E.	10.58
24	3. Cumulus	1,197.9	2,379.8	5,056.4	1: 5,578.9	S. 36° 59′ E.	11.60

(2) **The inclination of the axis of the storm determined by means of cloud photography.**—Having seen the great value of photogrammetric observations of clouds in ascertaining the existence and position of distant cyclones, let us proceed to investigate a point of even greater importance, which is the relation of the actual height observed in a given cloud under the influence of a cyclonic disturbance to the mean normal height of the type of clouds to which it belongs. This relation enables us to tell toward which quadrant of the typhoon its axis is inclined and in which, consequently, the lower air currents or winds will be most violent and hence the meteor most destructive. A glance at Plate II will convince us that the greater or less height of the cirri emerging from the vortex of a cyclone is an indication of a corresponding inclination of its axis. For, let the line MN represent the normal altitude of the cirri when the axis is vertical. If we now suppose that the axis assumes the position OE′—that is, inclines in the direction of the trajectory MN—it is evident that the height of the cirri which are in front of the typhoon will be diminished by the amount *np*, being now represented by the line MP, while at the rear their height will be correspondingly increased. If, therefore, the axis has an inclination toward any of the quadrants, the altitude of the cirri will decrease in that quadrant and, as a consequence, the altitudes of the intermediate and lower clouds also; in the opposite quadrant, however, the altitudes of the various clouds will increase. It need hardly be mentioned that an influence corresponding to their position must likewise be felt in both the other quadrants.

Having ascertained the mean height of each class of clouds at a certain station, a considerable increase or diminution with respect to the said mean height will suggest the direction of the inclination of the axis, even without a comparison of the heights, one observation being sufficient for it. Hence it follows that the severity of the typhoon depends in a great measure on the inclination of the axis, because the winds on that side toward which the axis is inclined will be very near the ground and, consequently, very violent; and, on the contrary, the winds and clouds will move at a higher level on the opposite side. It may well be asserted that from the height of the clouds it may be determined in which quadrant of the cyclone the lower currents will be most violent. We shall illustrate this by a few practical instances.

Practical examples.—We have said on page 61 concerning the cyclone which passed by Aparri on July 28, 1896, that on crossing near that station and, consequently, through the interior of Luzon, the axis was inclined toward the posterior part of the cyclone. Let us see how the measurements of the clouds confirm this assertion. In fact on the 25th the cirro-cumuli of the typhoon were measured and found to be almost 8,600 meters high. This height of the cirro-cumuli indicated that the inclination of the axis was toward the opposite side, and this was confirmed by the measurements of the 27th, according to which the cirro-cumuli were more than 3 kilometers lower and proceeded from a different side of the typhoon. (See table for July, 1896, p. 117.)

We find another example of this description in the photographic measurements of October 7 and 10, 1896. When dealing with the measurements of October 7 we said that the cirro-cumuli were moving at a low level—the reason for which was, undoubtedly, that at that time the axis of the cyclone was inclined in the direction of the Archipelago. This inclination it retained as long as the vortex moved over the Pacific—that is, up to the 9th—because the winds in the front were the strongest at the most easterly of the northern stations, as, for instance, at Aparri and Tuguegarao. The inclination of the axis must nevertheless have changed greatly, as the vortex was passing over the interior of the island, to which conclusion we are brought by the violence of the winds at Vigan and Bolinao. During this time there was no chance of making photographic measurements, as the sky was overcast and there were incessant squalls. On the 10th, however, the altitude of the cirrus was measured and ascertained to be more than 15 kilometers, which is considerably higher than its normal level, and suggests the conclusion that the axis had reassumed the inclination toward the anterior quadrants, similar to the inclination which the storm had in the Pacific. The conditions of the wind at Vigan on the morning of the 10th confirm this supposition. Early in the morning the winds were very strong, but they had considerably moderated at 10 o'clock, the barometer then being still very low, so that at the time of the measurement of the clouds at Manila, at 11.37 a. m., no strong winds were blowing at Vigan; the axis of the cyclone must therefore have had an inclination toward the anterior quadrants.

The photogrammetric observations of June 19 and 20, 1897, furnish another interesting example. If we compare the photographic measurements made on the above dates and printed in the table on page 119, we find that the cirri of the 20th had almost double the altitude of those of the 19th, the latter being considerably below the average level of this type of cloud. Consequently, on the 19th the cyclonic axis was inclined toward the anterior quadrants of the cyclone, and supposing that it retained this inclination on the 20th, it was but natural that the cirri of the latter date, issuing from the left half of the storm were much higher. A further proof of the asserted inclination is afforded by the lower air currents at Aparri, the station which lay nearest to the Pacific vortex.

Notice.—In conclusion we state that, according to the extent of the whole body of the typhoon, the influence of the inclination of the axis on the inferior currents is little noticed in the outskirts of the storm and gradually increases in the neighborhood of the vortex, as experience teaches. Moreover, in view of the nature and structure of the typhoon, it does appear that the variation of the axis or nutation can not be rapid, but must be slow and gradual as the typhoon passes from the sea to land or crosses land and mountain ranges according to the greater or less resistance of the obstacles it encounters.

(3) **The distinction between the true and false cirri as shown by photography.**—The question has finally to be answered whether the measurements of the altitudes of clouds offer us a useful method of distinguishing the true from the false cirri, a point of no less importance than the previous ones.

We must admit that this mode of determination is of no practical value to sailors, because it is impossible to execute such measurements on board ship. Nor is it very likely that sailors will draw any direct benefit from the other two matters which we have discussed in this chapter. Our sole purpose is to present new methods which will enable a fixed observatory, well provided with the requirements for photogrammetric work, to foresee atmospheric disturbances and consequently give timely warnings of the impending dangers for the benefit of those who navigate the imperiled seas.

In order to distinguish the true from the false cirrus sailors may attend to the following indications which have also been given above:

(1) If the convergent cirri seem to rest on masses of cumulo-nimbus they are false.

(2) If we observe that the convergent cirrus does not belong to the masses of cumulo-nimbus and the convergence is very persistent, we have to deal with true cirri which are moving slowly.

(3) If the convergence does not continue we can not conclude that the cirri are false, but in this case the sailor must apply other critera: (*a*) If the nucleus of the convergent cirri moves on rapidly we are justified in concluding that the cirri are false; (*b*) if the nucleus follows the direction of the cumulo-nimbus, even if the movement is not rapid, the cirri are also false; (*c*) but if the convergence is not persistent, because the cirrus disappears when the sun has a high altitude, which sometimes happens, we are unable to come to any final decision. If the cirri reappear

in almost the same position when the sun is setting we may conclude that they are true ones. If the convergence disappears because other clouds are forcing themselves underneath the cirri, a final decision is also impossible and the observer must wait for their reappearance.

(4) If the same convergence is observed at stations that are far distant from each other the clouds forming it are true cirri. This means is, however, only applicable at central observatories which are in telegraphic connection with the respective stations.

But in order to return to the main point at issue: During the time from June 1, 1896, to July 31, 1897, it was found that the altitude of the false cirrus was considerably less than that of the true cirrus. The latter has a mean altitude of about 11 kilometers, while the false cirri do not exceed the height of clouds of intermediate altitude (7 kilometers). Thence it follows that in doubtful cases we may, generally speaking, suppose that the cirri are true if their altitude exceeds 11 kilometers. We must, however, remark that during May, July, and November the false cirri appear at greater altitudes. But should, during one of these months, arise the necessity of distinguishing the cirri, we have besides the altitude the indications above mentioned which will enable us to come to a certain conclusion.

But there is another circumstance which allows us to obtain information as to the character of the cirrus—that is, the direction of its movements. If this be ascending and the altitude not very great, then the cirri are most likely false. Of 23 photographic observations of false cirrus, only 3 had a descending movement.

From what has been said it is concluded that the height as well as the direction of the cirrus may contribute toward the solution of any doubt regarding the truth or falsity of the same.

CHAPTER IV. INDICATIONS GIVEN BY THE DIRECTIONS OF THE WIND.

In the three preceding chapters we have studied the relations existing between the higher atmospheric currents, as manifested by the forms and directions of the clouds, and the position and movement of the cyclonic vortex. The present chapter we will devote to the investigation of the connection of the same data of a cyclone and the lower currents or winds.

The causes which modify the direction of winds.—It is evident that the lower air currents are greatly influenced by exterior circumstances, such as the unequal friction against the various elevations and depressions, the topographical conditions of the regions traversed, the transition from the sea to continents or islands and vice versa, the influence of variations in the thermal and hygrometrical conditions of land and sea, and of other similar causes. The lower air currents offer us, nevertheless, direct symptoms, although they are not to be counted among the precursory indications, since conclusions drawn from them are of value only when the observer has already entered the area of the cyclone.

The direction of the wind on the open sea.—On the open sea the data derived from the lower air currents are of an equal and even of a higher importance than those drawn from the upper currents, inasmuch as the former are scarcely affected by disturbing influences, and as to the latter, the sailor is unable to make any observations on the upper currents when the danger approaches and he has to form a decided opinion. In these circumstances he must rely on the valuable information supplied by the lower currents, and this is the very reason they are turned to such good account in the cyclonometer.

The condition necessary in order to profit by the directions of the winds.—The first condition necessary in order to make use of the wind directions as a manifestation of the impending cyclone is a thorough knowledge of the normal directions of the winds in the particular region in which the observer finds himself. All that has hitherto been published about the general and local normal air currents, at any rate as far as the zone of the Archipelago is concerned, is so incomplete that it is necessary to treat them here more in detail.

The general, normal, and local air currents.—We draw a distinction between general winds, or trade winds, which are caused by the thermal differences between the polar and equatorial regions, and local winds, which are caused by the various thermal conditions of the continents and ocean or of islands and the adjacent seas. If these differences last for some time these winds are called "monsoons," but if these heat variations have a diurnal period the winds are termed "sea breezes" respectively "mountain breezes."

There is no essential difference between these breezes and the monsoons, since both depend essentially upon the geographical and even topographical position of the different regions, and they are only distinguished from each other by the duration of their periods, the changes which take place, and their greater or less extension. The essential difference between the general winds or trade winds and the monsoons is in this, that the general winds owe their existence to the normal differences of temperature corresponding to latitude, while the monsoons are due, not to the differences of normal temperature themselves, but to the differences between these and the temperatures which are brought about by local causes and which are more or less independent of latitude. Such are elevations and depressions of the earth's surface, the distribution of large and small continents and seas, the vicinity of large continents or extensive oceans to a given locality, etc.

In certain circumstances it may happen that the general winds and monsoons influence the local winds to so great an extent as to impart to them their own direction or at least modify their course in the direction of the resultant of the varied forces which they bring to bear upon them.

The normal winds, general and particular, in the Philippine Islands.—It is a well-known conclusion from the theory of atmospheric circulation that on the northern hemisphere the normal general winds should blow from the north throughout the entire year. In the intertropical regions, and consequently also in the zone comprising the Philippine Islands, they would take a northeast direction, owing to the earth's rotation.[1] The fact that this does not happen invariably in the Archipelago and the adjacent seas points to the existence of particular conditions which modify or even entirely change their normal direction. If we take in the Batanes group of islands, north of Luzon, Manila is, as to latitude, approximately midway between the extreme points of the Archipelago. We may, therefore, take the atmospheric movements observed at Manila as fairly typical of the Archipelago. Now, at Manila the normal winds come from northeast only during the months of October to February. In March and April they blow still from the east, but during the rest of the year southerly directions, ranging from southeast to southwest, predominate.

Are the local winds of the Philippines true monsoons?—Since the winds from the northeast are the general or trade winds, they are improperly called monsoons, although it is true that during the months from October to March the thermic conditions of the Philippines are so widely different from those of the immense Asiatic continent, with its intense cold in the interior during this period, that strong air currents are set up in a north to south direction, which being deflected by the earth's rotation assume a northeasterly course. These currents, having thus the same direction as the trade winds, reënforce the latter with the result that during those months the "northeasters" blow rather hard, as is abundantly shown by experience on the high sea and the eastern coasts of the Islands. Solely for this reason the northeast trades may be called monsoons.[2]

During March the temperature gradually increases over the Asiatic continent, while it diminishes over Borneo and the continent of Australia in the southern hemisphere. The partial disappearance of the conditions which give rise to the northeast winds effects a corresponding falling off of these winds themselves at the very time when the accentuation of thermal differences between the Philippines and the above-mentioned regions augments the normal general southeast winds of the southern hemisphere to such a degree that, crossing the equator,[3] they reign all over the Philippine Islands and the southern part of the China Sea.[4] Consequently also the winds experienced from March to June are incorrectly termed southeast monsoons, because they are in reality nothing but normal general winds of the southern half of our globe, strengthened, it is true, by a monsoon, which in the Philippines and southern China Sea prevail against the enfeebled normal currents of the northern hemisphere.[5]

But, granted that for the reasons exposed neither the northeast nor the southeast winds can be properly called monsoons, are not at least the southwest currents predominant during the months of June, July, August, and September true monsoons of the Philippines? From the point of view of the meteorologist this question is at least interesting, but it is of great importance for the forecasting of cyclones, and hence we must give it due attention.

We confess that this is a ticklish point, especially since both ancient and modern writers on the subject vouch for the existence of the southwest monsoon in the Philippines and south China Sea. Without preconceived notions of any kind, we shall treat the question on the basis of well-established and hence reliable facts. Nor do we claim for the outcome of our investigation greater authority than is warranted by the nature of the facts themselves, their frequency, their number, and the variety of conditions under which they happened, as is the case in every conclusion in the domain of experimental sciences arrived at by induction.[1]

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[1] See "Winds of the Globe," by Coffin. Washington, 1876, p. 665.

[2] See the excellent work, "Memoir on the Winds and Monsoons of the Arabian Sea and North Indian Ocean," by Dallas. Calcutta, 1887, p. 29.

[3] "Die Klimate de Erde," by Woeikof.

[4] "A Popular Treatise on Winds," by Ferrel; New York, 1890. p. 203. Scott's "Elementary Meteorology," London, 1883, p. 265.

[5] Coffin, "The Winds of the Globe."

This being supposed, we frame the question thus, Are the southwest winds, which during certain months of the year prevail in the Philippine Islands and the tropical portion of the China Sea, monsoons in the scientific sense of the word? In our modest opinion they are not true monsoons, but air currents corresponding to cyclonic vortices or at least due to abnormal changes in the atmosphere. It is clear that, put in this form, the question is not about the mere matter of a name—that is, whether the dominating southwest winds of June, July, August, and September may be called monsoons or not—but rather whether from their frequency and force we can infer the existence of a cyclonic center or atmospheric disturbance, and consequently whether or not we can regard them as signs of a typhoon or at least of an atmospheric depression.

The writers who in some way or other have dealt with this question suppose that the beginning of the southwest monsoon is some time in the month of May, so that according to their views the monsoon prevails in the month of June. The constant and attentive experience of many years shows that this is not the case in Manila and neighboring seas. In order to prove this it will only be necessary to cite several paragraphs of the meteorological observations corresponding to the month of June for several years.

We read in the "Revista Meteorológica" for June, 1890:

> What so often attracts our attention is that the winds of the second quadrant prevail at a period which (according to many) belongs entirely to the southwest monsoon. Bearing in mind the observations above set forth this is of great interest for general meteorology and should not be left unnoticed when dealing with the movements of the atmosphere.

June, 1892:

> Although we have entered into the period of the southwest monsoon, the wind directions of the second quadrant are still prevalent; this may be said not only as to the lower winds but also as to the upper currents which carry the clouds. This phenomenon is explained by the two principal atmospheric disturbances which were observed over Luzon; their center of lowest pressure lay over the China Sea. As soon as the center of disturbance of the first eddy reached the north of Luzon the winds naturally came from the third quadrant.

June, 1893:

> The meteorological observations of the month have again shown that the changes of the monsoon do by no means take place with the almost mathematical precision attributed to them by many authors; for in the depressions which crossed the Islands in May the air currents of the first and second quadrants have again appeared with such steadiness as if we were still in the middle of April.

June, 1894:

> From a comparative study of the direction of the surface winds and the lower clouds, we may draw the important conclusion that in the month of June the currents from the third quadrant appear much more frequently under abnormal than under normal conditions of the atmosphere. We shall confine ourselves to the Junes of 1890 to 1894. June, 1890, was a month which showed so little atmospheric activity that the absolute minimum did not fall below 755.17 millimeters (29.73 inches). Nevertheless, owing to the influence of distant depressions, the barometer was relatively low during the first days of the month—that is, from the 2d to the 5th, moreover from the 13th to the 15th, and from the 22d to the 25th. But these were the only days on which the winds from the third quadrant prevailed. During the rest of the month not only the direction of the clouds but also that of the winds was from the second quadrant. June, 1891, on the contrary, was marked by continual atmospheric activity, not specially intense, it is true, for the barometer did not fall below 755 millimeters (29.72 inches), but persistent to such a degree that the barometer remained low from the 6th to the 17th, and from the

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[1] A meteorologist well qualified to speak with authority on the southwest monsoon of the China Sea holds that these winds come from the southern hemisphere. This supposition does away with part of the difficulty, because it is ultimately equivalent to the admission that the frequent atmospheric alterations which occur in the higher latitudes deflect the trade winds from the south, changing them into winds from the third quadrant. There is, of course, no objection to calling them monsoons in a wider sense of the word, as we have said regarding the north trade wind strengthened by local causes. See also "The Winds of the Globe," by Coffin, and "Discussion and Analysis of the Winds," by Woeikof, p. 733. Dove also maintains that the southwest monsoon of the Arabian Sea and the Indian Ocean is simply the deflected southeast trade wind. This opinion was confirmed many years later by Dallas in his memoir, "The Winds and Monsoons of the Arabian Sea and North Indian Ocean," Calcutta, 1887, p. 20.

20th to the end of the month. Now, on all these days the lower air currents came from the third quadrant; the winds had, by application of Lambert's formula, a mean direction from southwest and the clouds from west-southwest. During June, 1892, Manila was under the influence of an atmospheric disturbance by which the barometer fell to 752.91 millimeters (29.64 inches) from the 6th to the 12th, and during these days the winds blew exclusively from the third quadrant. We do not wish in any way to maintain that only southwesterly winds blow during atmospheric disturbances; it is of course understood that, if a cyclone is forming in the south of Manila, or if one crosses the southern part of the Archipelago, the winds must blow from the first or second quadrant, but specially from the former. This was the case in June, 1892, and June, 1893, during which, by the influence of small cyclones which were formed in the Jolo Sea and in the China Sea, the resultant of the lower air currents and of the cloud directions lay in the first quadrant.

As to the present month of June—that is, 1894—the currents from the third quadrant prevailed; that is to say, a cyclonic center was being developed to the north-northwest of Manila, and another ran by the Pacific, as will be seen later when treating of atmospheric disturbances. The facts above mentioned not only confirm what was said in the reviews of June, 1892 and 1893, but also give us ground to suspect the soundness of the basis upon which the month of June is counted among the months during which the so-called southwest monsoon prevails.

June, 1897:

If we examine the wind conditions of June, 1897,[1] we shall find that during the first two decades the winds, without any exception, came from an easterly direction, or from the second quadrant, and that during the third decade of the month they came from a southwesterly direction, or from the third quadrant, and this in consequence of various depressions which passed by to the northward. If on the 4th, 5th, 6th, 11th, and 12th of June the wind blew occasionally from the third quadrant, the reason of this must be looked for in two cyclones which passed far to the north. It is but natural that the wind took this direction during the period of the sea breeze which at Manila blows from the third quadrant. In June the southwest monsoon is not prevalent; any southwesterly direction of the wind owes its origin to cyclones.

At Manila, therefore, the prevalent winds during June are not those of the third quadrant but those of the second, nor can the winds blowing occasionally from the third quadrant be regarded as true monsoons; they are nothing but the effect of atmospheric disturbances. We go a step further and suppose that our assertion has not been proved by what has been said and that the southwest monsoon in the Philippines is only delayed in its arrival, the southeast trade wind still prevailing during June. But if we determine the mean frequency of the different wind directions for July we shall find that this is not the case. We have drawn up a table from the observations published in the "Boletines Mensuales del Observatorio." In order to obtain wind direction prevalent under normal conditions we have omitted the days which were evidently affected by cyclones, not, however, the southwest winds which must be assigned to the sea breeze, which at Manila is in this direction.

FREQUENCY OF THE DIRECTION OF THE WINDS AT MANILA DURING JULY.

Year.	N., NNW.	NW., WNW.	W., WSW.	SW., SSW.	S., SSE.	SE., ESE.	E., ENE.	NE., NNE.	Calms.
1890	1.7	1.5	0.3	0.9	1.6	0.9	1.5	1.3	3.7
1891	1.0	1.1	.4	.6	4.4	1.4		.5	3.9
1892	1.4	.6	.5	.7	3.1	1.6	3.1	1.7	2.3
1893	2.0	1.5	1.3	1.0	1.5	1.5	2.2	3.2	1.9
1894	1.3	1.4	1.3	.7	2.5	1.2	1.4	2.2	4.2
1895	.8	.6	1.1	.8	1.8	.9	.9	1.7	6.3
1896	1.5	1.9	1.0	.8	2.5	2.7	1.1	1.8	3.3
1897	.8	.7	1.3	1.3	1.9	2.6	1.8	1.8	6.3
1898	.5	.7	1.0	.8	1.6	2.5	2.1	.7	9.8
1899[1]	.5	1.2			.9	1.1	1.5	1.0	2.0
1900	1.2	2.2	2.3	1.3	1.8	2.6	3.9	2.2	4.3
Total	12.7	13.4	10.5	8.9	23.6	19.0	19.5	18.1	48.0
Mean	1.2	1.2	1.0	.9	2.1	1.7	1.9	1.6	4.4

[1] Manila has been influenced by cyclonic centers throughout the whole month. See "Boletin Mensual" for July, 1899, p. 112.

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[1] "Boletin Mensual," June, 1897.

Applying Lambert's formula we have from the table that the winds which are prevalent in July during periods of normal conditions blow from the second quadrant—that is, they are the trade winds of the southern hemisphere; the southwesterly winds of July are, therefore, not true monsoons.

We add here by way of confirmation what was written in the meteorological review of the month of July, 1897:

> In the observations of the present month of July we find a convincing proof of the opinion often given in our publications, that the winds from the southwest, even in the months of July, August, and September, are here in the Philippines probably not the true monsoon, inasmuch as they only rule when we feel the influence of depressions which run in the northern quadrants. In fact if the table of "extreme values" be examined, it will be seen that in the whole month there only dominated winds from the third quadrant from the 1st to the 5th, the 17th and 18th, and from the 23d until the end of the month. Well, then, from the 1st to the 5th the last depression of the preceding month which moved away by the north exerted an influence even in our Archipelago. From the 23d to the end of the month it will be seen by what we shall have to say later on that we found ourselves under the influence of depressions which ran also in the northern quadrants; finally, on the 17th and 18th there existed in high parallels, in Japan, a center of low pressure, the outermost isobars (29.73 inches = 755 millimeters) of which reached almost the extreme north of the Island of Formosa, as may be seen in the meteorological maps daily published by the Central Observatory of Japan. And, indeed, we must confess that we felt true satisfaction when after having suspected the existence of this cyclonic center solely by seeing that there continued to blow in Manila, even beyond the hours of the breeze, the winds from the third quadrant, we saw our suspicions fully confirmed upon examining the cited maps. During the remainder of the month the winds from the southwest have blown rarely and only in the hours of the breeze, which, as is known, comes here in Manila from the said direction.

We shall get similar results if we examine the meteorological observations for the months of August and September. The conclusion derived from these scientific observations is greatly strengthened by the fact that from time immemorial the Indian races inhabitating the western coasts of Luzon use precisely the month of August for their boat expeditions to the different ports of the south in order, as they express it, to profit by the little monsoon—that is, the winds from the first and sometimes the second quadrant—in other words, winds having an easterly direction. And in fact, owing to the rare occurrence of depressions during August, the winds of the third quadrant are exceptions, while if they were the true monsoon of the China Sea—that is, normal winds—the aforesaid popular belief could not have arisen.

What we have said will suffice in order to justify our assertion, especially as according to the opinion of those who have studied the monsoon this wind ought to have reached its full predominance over our Archipelago in July. But there are still other sound reasons which may be adduced. Supposing that the winds of the third quadrant in the Philippines and the China Sea were true monsoons and, therefore, periodical and regular, owing their origin to a disturbance of thermal equilibrium, but owing to the same action differing from that which gives rise to the trade wind, there is no sufficient reason for their extension being so limited as is the case in the south of the China Sea and in our Archipelago. How does it happen that neither in the western Carolina Islands, for instance, nor in the Batanes Islands, nor in the Channels of Bashi and Balingtan, nor on the coast of China commencing with the twentieth parallel, and in other neighboring regions and seas having the same physical conditions as our Archipelago, do any winds of the third quadrant prevail during June, July, August, and September, but instead thereof only easterly winds? It will not do to say that the southwest monsoon in the Philippines and in the China Sea owes its origin to the influence of the true monsoon of the Indian Ocean. Because, if this were the case, the monsoon must also be felt over the seas and lands lying between; but neither on the west coasts of north Borneo and the adjoining seas, nor in the whole Straits of Malacca and the countries adjacent thereto, nor in Sumatra, do any winds from the third quadrant blow from June till August, but only the trade winds of the southern hemisphere.

From all that has been said we must come to the conclusion that the winds of the third quadrant which prevail in the Philippines during July, August, and September are not monsoons but winds of a cyclonic character. What continuous atmospheric disturbances must, however, exist over the Archipelago and the south of the China Sea in order that these winds can be prevalent for such a length of time? If we examine the tracks of the cyclones which we have given in this book we shall find: (1) We meet the centers which cross the Archipelago in the months of July, August, and September, at least in the latitude of 12° north; accordingly the influence of the cyclones must make itself felt in such a manner from the time of their entry into the region of the Archipelago up to the time in which they reach the continent that the corresponding cyclonic winds, the winds of the third quadrant, shall develop in the greater part of the Archipelago and in the south of the China Sea for an interval of several days. (2) During these three months the cyclones recurve approximately to the west of the Bashi Islands; the consequence is a long-continued influence, felt over the whole Archipelago and the south of the China Sea. Moreover, it may be that the process of recurving takes place slowly—it sometimes takes five days—or that the tracks are greatly inclined toward north, and that thereby the effect is still prolonged. In this manner it is possible that the influence of a single storm field often lasts for twelve, fourteen, and even more days. If now, as is really the fact, one cyclone may follow another at intervals of four or five days only during these three months, it is easy to understand that the southwest winds may blow for a great many days.

Moreover, centers of depression appear frequently in June and July in the northwest, north, and north-northeast of Luzon, developing slowly and remaining sometimes stationary for several days. They have as a consequence air currents and squalls belonging to the third quadrant, which are known among the natives as "collas" (streak winds) and are generated either by the influence of one or more depressions traveling slowly to the northward, or by a depression which is recurving slowly and is advancing to the north, or else, finally, by a center which is not changing its position. Their influence, however, is always felt for a long time in winds and squalls from the third quadrant.

Experience teaches us that at Manila (and we suppose that this is also the case in the China Sea), when a cyclone appears to the east of Luzon over the Pacific, the winds of the third quadrant advance in such a manner that there is not only a complete convergence brought about but that they already commence to predominate, when the center lies almost to the east of the observer. This is probably due to local influences. It is, on the other hand, a guaranteed fact that the advance of the southwest winds in Manila is all the more marked the greater the angle is which the tangent to the track makes with the parallel of latitude. This angle increases from April to August, and hence it follows that during this period the southwest winds gradually become more frequent. But what is the reason of this strange phenomenon? We must look for it in the southeast trade wind only, which certainly is the normal wind for the months of April, May, and June, and most probably for July and August also. If a cyclone approaches the observer from the east light winds would have to set in from the fourth quadrant as long as the storm remains at a considerable distance. This is, however, not the case, as experience teaches. On the contrary, we always notice a backing of the winds toward the third quadrant. But this can not be explained in any other way than that the winds of the fourth quadrant, diverted by the southeast trade, give as a resultant a wind direction from the third quadrant, and as the trades are, as to their nature, light, it is easily intelligible that they can exercise influence only upon the outermost cyclonic winds.

Practical conclusion.—If winds blow for a long time from the third quadrant in the China Sea or in the Archipelago (these must not be confounded with the ordinary land and sea breezes) they are a sign that in the quadrant lying to the north of the observer there is a depression which is more or less distant, according to the readings of the barometer. If during the months of June, July, August, and September a sailor is navigating the seas of China, Jolo, Mindoro, or any other of the interinsular seas and finds that the southwest winds are blowing steadily, he can be quite sure that there is a cyclone vortex situated in the north. But, unfortunately, many sailors have the idea so firmly fixed in their minds that the southwesters are nothing more than monsoons or "collas" that when, in navigating the above-named seas, they find the steady southwesters freshening they often continue their northern direction, even when the barometers are relatively low, persuaded that the force of the wind will be the same during the whole of the voyage, while in reality they run into a great danger from which they can not always escape.

The direction of the wind as an indication of a cyclone.—A sailor who in the seas adjacent to the Philippines suspects that he is within the influence of a far-distant cyclone has, before everything else, to settle the question whether the prevailing winds are normal or not. For this purpose he will do well to make use of the graphical representation of the directions of the wind and the clouds at Manila (Pls. XXXII and XXXIII). He must not, however, forget that the winds from the third quadrant are suspected, and those of the fourth quadrant still more so, because there is no season in which they predominate.

We have, according to calculation and observation, graphically represented in a diagram the directions of the wind all around the center of a cyclone, dividing the eddy from the outside to the center into the zones A, B, C, D. By the aid of the figure we are enabled, from the direction of the wind and the readings of the barometer, to find the direction in which the cyclone lies and its distance also.

Practical rules.—(1) Should we observe within the range of a cyclone winds between the northwest and northeast we may be sure that the center lies in the direction of the second quadrant and that it is approaching.

(2) If the observer is in the zones A, B, C: (*a*) With wind northwest to southwest, the center is approaching the meridian of the observer by the north; (*b*) with wind from southwest, with a tendency to south, the center has passed by to the north; (*c*) with winds from the first quadrant or a northerly direction, with a tendency to east, the center is approaching the meridian of the observer by the south; (*d*) with winds between northeast and southeast, the vortex has passed by the south.

(3) If the observer is in the zones A, B, C: (*a*) With wind from the fourth quadrant or a westerly direction, veering toward the third, barometer steady or rising, the center is recurving to the east of the observer; (*b*) with winds from the second quadrant, veering to the third, barometer steady or inclined to fall, the center is recurving to the west of the observer.

(4) The observer in zone D: (*a*) If the sky clears up and the wind falls the center is passing over the place of observation; (*b*) if the wind be veering, north to south by way of west, the center is passing close to the place to the north of it; (*c*) if the wind is backing from north to south by way of east the center is passing close to the place south.

These rules are especially valuable for use on the high sea, as there no topographical conditions can exert any influence upon the air currents, as is the case on shore. We intend to discuss the simultaneous influence of several centers, when dealing with their anomalies. If the observer suspects any external influence upon the wind directions he can avail himself of the indications offered by the directions of the clouds, according to the laws of cyclonic circulation already explained.

WORKS WHICH MAY BE CONSULTED IN CONNECTION WITH CHAPTER IV.

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CHAPTER V. INDICATIONS GIVEN BY THE BAROMETER.

As we have shown in Chapter IV of Part I, the rise and fall of the barometer is, strictly speaking, no positive test, but is, nevertheless, an indication of the greatest importance. We do not intend to speak here of the extraordinary advantages which may be derived from barometrical observations made simultaneously at many stations and which, when transmitted by telegraph to a central observatory, are of the highest value in order to facilitate the recognition of an atmospheric disturbance and to follow its advance. We wish only to call special attention here to the advantage which an isolated observer, a sailor, can derive from the careful observation of his instrument.

The correction of the barometer and the normal reading of the barometer at the place of observation.—The observer must first of all know the instrumental error of his barometer. "There exists a widespread error among ships' captains," says Fr. Chevalier, "that it is not necessary to know the absolute readings nor, consequently, to know the instrumental error, but that it is sufficient to determine the relative readings of the barometer. A captain who knows what correction he has to apply when reading his barometer is in a position to say, from the less or greater fall of his barometer, whether it is caused by a high-pressure area which is moving off or by a low-pressure area which is approaching." The relative variations will be the same in both cases, but instead of the sailor understanding from his barometer readings the precursory signs of a cyclone, he is liable to deduce therefrom indications of a false security which may expose him to great perils.

The knowledge of the normal level of the barometer in the district in which the observer is situated at the time is also indispensable. In the following tables we give these values for the principal places of the Far East. From these data it will be easy to find the normal pressure for many other points, either directly or at least by interpolation. Thus the navigator can find with sufficient approximation the normal barometric height for the different points of the China Sea, the Formosa Straits, a great part of the Pacific Ocean, the Yellow Sea, and for all the interinsular seas of the Archipelago. For the Philippines and the adjacent seas a simple and reliable rule may be stated thus: The mean of the barometric readings at 10 a. m. and 4 p. m., with southerly winds, or of 10 a. m. and 3 p. m., with northerly winds, gives us the mean daily pressure under normal conditions.

The table itself needs no explanation. It will be seen that the various places are arranged according to increasing latitudes. For the convenience of those who possibly are less familiar with barometer readings expressed in the metric system we give the same table also in inches.

MEAN BAROMETER LEVELS AT THE PRINCIPAL POINTS IN THE FAR EAST.

I. METRIC SYSTEM.

Place.	North latitude.	Longitude.[1]	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	° ′	° ′												
Singapore	1 17	103 51	759.2	759.6	759.5	758.4	758.2	758.4	758.4	758.8	758.6	758.8	758.3	758.5
Sandakan	5 40	118 03	58.8	59.3	57.5	58.0	57.1	57.0	57.3	57.8	57.0	58.8	56.5	57.0
Jolo	6 03	120 59	58.0	59.0	57.5	58.2	57.2	57.4	57.2	58.0	57.5	58.5	56.7	56.9
Sigaboy	6 36	126 07	57.0	58.5	57.7	58.0	57.4	58.2	56.8	58.6	57.3	58.0	57.0	56.6
Isabela de Basilan	6 43	121 05	58.0	59.0	57.7	58.4	57.4	57.5	57.1	58.1	57.7	58.3	56.9	57.0
Zamboanga	6 54	122 03	58.0	59.0	57.7	58.4	57.5	57.5	57.1	58.1	57.7	58.3	57.0	57.0
Mati	6 56	126 14	57.0	58.5	57.7	58.0	57.4	58.2	56.8	58.6	57.2	57.9	57.0	56.7
Mount Apo	6 58	125 08	57.2	58.5	57.7	58.2	57.4	58.1	56.8	58.5	57.2	58.0	57.0	56.9

[1] East of Greenwich.

MEAN BAROMETER LEVELS AT THE PRINCIPAL POINTS IN THE FAR EAST—Continued.

I. METRIC SYSTEM—Continued.

Place.	North latitude.	Longitude.[1]	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	° ′	° ′												
Davao	7 01	125 35	757.2	758.5	757.7	758.2	757.5	758.1	756.8	758.5	757.2	758.0	757.0	756.9
Caraga	7 15	126 30	57.0	58.5	57.7	58.0	57.5	58.2	56.8	58.6	57.1	57.8	57.0	56.9
Point Punsan	7 15	126 33	57.0	58.5	57.7	58.0	57.5	58.2	56.8	58.6	57.1	57.8	57.0	56.9
Korror	7 20	134 34	57.2	58.0	58.5	57.0	57.7	59.0	56.8	59.3	56.0	57.5	56.4	56.9
Tamontaca	7 11	124 09	57.7	58.8	58.8	58.5	57.5	57.9	57.0	58.3	57.8	58.3	57.2	57.1
Pulo Obi	8 27	104 51	61.2	60.5	56.0	57.0	56.0	55.5	56.3	57.0	56.0	------	57.0	58.0
Tagoloan	8 33	124 40	58.0	59.0	58.2	58.6	57.8	57.8	57.4	58.3	57.4	58.3	57.5	57.7
Dapitan	8 40	123 23	58.2	59.2	58.2	58.6	57.8	57.8	57.3	58.2	57.7	58.2	57.5	57.7
Tandag	9 02	126 10	58.0	59.2	58.2	58.6	57.8	58.0	57.3	57.5	57.2	58.5	57.5	57.7
Yap	9 29	138 05	58.2	58.8	60.0	58.2	58.5	59.4	56.8	59.5	57.0	58.2	56.0	57.8
Gigaquit	9 32	125 44	57.8	58.8	58.2	58.0	57.9	58.1	57.0	58.5	57.0	57.8	57.4	57.2
Taganaan	9 44	125 32	57.9	58.8	58.4	58.2	57.9	58.1	57.1	58.5	57.0	58.0	57.5	57.6
Surigao	9 47	125 29	58.0	59.0	58.5	58.4	58.0	58.1	57.2	58.4	57.0	58.0	57.5	57.7
Dinagat	9 58	125 35	58.2	59.0	58.8	58.4	58.0	58.1	57.2	58.4	57.0	58.0	57.6	57.8
Pulo Zapatu	9 59	109 03	61.3	60.8	56.5	57.2	56.0	55.7	56.4	56.9	55.2	58.3	57.2	58.7
Cebu	10 18	123 54	58.7	59.5	59.0	59.0	58.0	57.9	57.6	58.2	57.3	58.3	57.7	58.2
Cape St. James	10 20	107 05	61.4	61.0	56.2	57.2	56.0	55.5	56.2	56.9	55.1	------	57.5	58.8
Carlota	10 25	123 01	59.0	59.8	59.0	59.1	58.0	57.7	57.8	58.1	57.6	58.0	57.7	58.2
Iloilo	10 42	122 35	59.3	60.0	59.2	59.2	58.0	57.7	57.9	58.0	57.7	58.1	57.8	58.4
Saigon	10 47	106 42	61.5	61.0	56.2	57.2	56.0	55.0	56.0	56.8	55.0	------	57.5	59.0
Cape Padaran	11 35	109 09	61.5	61.0	56.8	57.3	57.0	55.7	56.2	56.6	55.0	------	57.8	59.0
Calbayog	12 06	124 38	59.3	59.8	57.5	59.0	58.2	58.1	58.0	58.1	57.0	58.4	58.0	58.8
Batag	12 40	125 01	59.4	59.8	59.6	58.8	58.2	58.1	58.0	58.1	57.0	58.4	58.2	59.0
Cape Varella	12 54	109 34	61.7	62.0	57.0	57.6	56.0	55.7	56.0	56.4	54.5	57.3	58.0	60.0
Banton	12 56	122 04	60.2	60.5	60.1	59.5	58.2	57.5	57.3	57.8	58.0	58.3	58.3	59.5
Albay	13 09	123 42	59.9	60.2	60.0	59.2	58.3	58.0	57.8	58.0	57.5	58.5	58.5	59.4
Agaña (Island of Guam)	13 28	144 45	60.4	61.5	61.6	61.0	59.6	60.0	59.5	59.2	60.5	60.2	59.5	60.0
Tabaco	13 21	123 43	59.9	60.2	60.0	59.2	58.8	58.0	57.8	58.0	57.5	58.5	58.5	59.4
Batangas	13 45	121 03	60.6	60.8	60.2	59.6	58.0	57.5	57.0	57.5	57.5	58.2	58.9	60.0
Point Santiago	13 46	120 39	60.8	60.9	60.1	59.6	58.0	57.4	56.9	57.4	57.6	58.4	58.9	60.0
Taal	13 53	120 55	60.8	60.9	60.2	59.6	58.0	57.5	57.9	57.5	57.5	58.8	58.9	60.0
Cabra (light-house)	13 54	120 01	61.0	60.9	60.0	59.6	58.0	57.3	56.9	57.3	57.2	58.5	59.0	60.0
Tayabas	14 01	121 34	60.7	60.8	60.3	59.6	58.1	57.6	57.0	57.5	57.6	58.0	59.0	60.0
Atimonan	14 02	121 51	60.7	60.8	60.3	59.5	58.1	57.6	57.0	57.5	57.7	58.0	59.0	60.0
Daet	14 04	122 56	60.4	60.6	60.3	59.2	58.2	57.9	57.1	57.7	58.0	58.3	59.0	60.0
Point Restinga	14 16	120 37	61.0	61.0	60.1	59.6	58.0	57.4	56.9	57.3	57.2	58.4	59.1	60.2
Santa Cruz, La Laguna	14 18	121 25	60.8	60.9	60.2	59.6	58.1	57.5	57.0	57.4	57.5	58.1	59.0	60.2
Cavite	14 29	120 55	61.1	61.0	60.2	59.6	58.0	57.4	56.9	57.3	57.2	58.2	59.2	60.3
Manila (Observatory)	14 35	120 58	61.1	61.1	60.2	59.6	58.0	57.4	56.8	57.3	57.1	58.2	59.2	60.4
Balanga	14 41	120 32	61.2	61.1	60.0	59.8	58.0	57.3	56.8	57.2	57.0	58.3	59.2	60.5
Bulacan	14 50	120 52	61.2	61.2	60.1	59.8	58.0	57.4	56.8	57.2	57.0	58.2	59.4	60.5
Bacolor	15 01	120 37	61.2	61.2	60.1	59.8	58.0	57.4	56.7	57.2	56.9	58.2	59.5	60.6
San Luis, Pampanga	15 03	120 46	61.2	61.2	60.1	59.8	58.0	57.4	56.7	57.2	56.9	58.2	59.5	60.6
Angeles	15 08	120 35	61.3	61.2	60.1	59.8	58.0	57.4	56.7	57.2	56.8	58.2	59.5	60.6
Mount Arayat	15 12	120 43	61.3	61.2	60.1	59.8	58.0	57.4	56.6	57.2	56.9	58.2	59.5	60.6
Iba	15 21	119 57	61.3	61.4	59.9	59.8	57.8	57.3	56.5	57.0	56.5	58.3	59.5	60.7
San Isidro	15 22	120 53	61.3	61.3	60.2	59.6	58.0	57.4	56.7	57.2	56.9	58.2	59.5	60.7
Palauig	15 27	119 53	61.4	61.4	59.9	59.8	57.8	57.3	56.5	57.0	56.5	58.3	59.5	60.7
Cabanatuan	15 29	120 56	61.4	61.3	60.2	59.6	58.0	57.4	56.5	57.1	56.9	58.2	59.5	60.7
Magalaoa	15 30	119 53	61.4	61.4	59.9	59.8	57.8	57.3	56.5	57.0	56.5	58.3	59.5	60.7
Tarlac	15 31	120 35	61.4	61.3	60.0	59.8	57.8	57.4	56.5	57.1	56.6	58.2	59.6	60.8
Bayambang	15 40	120 27	61.4	61.4	60.0	59.8	57.8	57.3	56.4	57.0	56.5	58.2	59.6	61.0
Paracel Island	16 00	111 48	62.5	62.8	59.0	58.6	56.5	55.7	57.6	56.0	54.1	58.9	60.0	62.5
San Quentin	16 00	120 50	61.4	61.4	60.0	59.6	57.8	57.2	56.4	57.0	56.8	58.2	59.8	61.2
Dagupan	16 04	120 19	61.4	61.5	60.0	59.8	57.8	57.2	56.4	57.0	56.2	58.3	59.8	61.2
Sual	16 05	120 05	61.4	61.5	59.9	59.8	57.8	57.2	56.4	56.9	56.1	58.3	59.8	61.2
Santo Tomas, Union	16 18	120 22	61.5	61.5	59.9	59.6	57.8	57.1	56.3	56.9	56.1	58.8	59.9	61.3
Agoo, Union	16 20	120 21	61.5	61.5	59.9	59.6	57.8	57.1	56.3	56.9	56.0	58.8	59.9	61.3
Cape Bolinao	16 29	119 46	61.5	61.6	59.7	59.8	57.6	57.1	56.3	56.8	56.0	58.4	59.9	61.4
Naguilian	16 34	120 26	61.5	61.5	59.9	59.6	57.6	57.1	56.3	56.8	56.0	58.4	60.0	61.4
Bayombong	16 37	121 12	61.5	6 .5	60.1	59.5	57.8	57.1	56.4	56.9	56.4	58.2	59.9	61.4
San Fernando de Union	16 37	120 19	61.5	61.5	59.9	59.6	57.6	57.1	56.3	56.8	56.0	58.4	60.0	61.4
Vigan	17 34	120 20	61.7	61.6	59.8	59.5	57.6	56.9	56.2	56.6	55.9	58.6	60.2	61.8
Tuguegarao	17 35	121 39	61.6	61.5	60.3	59.0	57.6	57.0	56.3	56.7	56.0	58.5	60.2	61.8
Laoag	18 13	120 34	61.8	61.7	60.0	59.4	57.5	56.8	56.0	56.4	55.8	58.9	60.6	62.4
Aparri	18 22	121 34	61.8	61.6	60.5	59.0	57.6	56.9	56.1	56.5	56.1	58.8	60.5	62.2
Cape Bojeador	18 30	120 33	61.9	61.8	60.5	59.4	57.5	56.8	56.0	56.3	55.9	59.0	60.7	62.5
Cape Engaño	18 35	122 05	61.8	61.6	60.8	58.9	57.7	56.9	56.2	56.6	56.4	58.8	60.5	62.2
Hoihow	20 03	110 20	65.0	64.0	61.0	59.4	56.8	55.5	54.9	55.3	55.0	60.1	62.5	64.8
San Antonio	20 22	121 55	62.9	62.0	61.6	59.4	57.6	56.5	55.8	56.1	57.0	59.6	62.0	63.2
Haiphong	20 52	106 40	65.8	64.5	61.0	59.4	56.8	55.0	54.5	55.3	55.1	60.0	63.0	65.9
St. John Island	21 40	106 36	65.7	64.5	63.0	60.0	57.0	55.5	54.8	55.1	56.1	61.2	64.0	65.5
Gap Rock	21 49	113 59	65.7	64.5	63.0	60.0	57.0	55.5	54.9	55.1	56.5	61.2	64.0	65.5
Formosa, South Cape	21 55	120 51	63.9	63.0	62.2	59.8	57.8	56.1	55.4	55.8	57.2	60.5	63.3	64.2
Macao	22 11	113 33	65.8	64.7	63.2	60.2	57.5	55.5	54.8	55.0	56.8	61.3	64.2	65.6
Hongkong	22 18	114 12	65.8	64.7	63.2	60.2	57.5	55.5	54.8	55.0	56.9	61.3	64.2	65.6
Breaker Point	22 56	116 22	65.8	64.8	63.2	60.4	57.5	55.7	55.0	55.0	57.1	61.3	64.2	65.6
Ngan-ping	22 59	120 13	65.0	64.0	63.0	60.0	58.0	55.9	55.3	55.6	57.3	61.1	64.2	65.0
Schan-tou	23 22	116 40	66.0	65.2	64.0	60.5	58.0	55.6	54.8	55.0	57.3	61.5	64.5	66.0
Canton	23 07	113 17	66.0	65.0	60.5	60.8	57.5	55.5	54.7	54.9	57.7	61.5	64.5	66.0
Chapel Island	24 10	118 13	66.3	65.5	64.0	60.5	58.0	55.6	54.8	55.0	57.5	62.0	65.0	66.4
Amoy	24 28	118 05	66.5	65.5	64.2	60.6	58.2	55.6	54.8	55.0	57.6	62.0	65.0	66.4
Okseu Island	24 59	119 28	66.5	65.4	64.0	60.5	58.2	55.6	54.8	55.0	57.9	62.1	65.0	66.3
Tamsui	25 10	121 25	65.9	64.5	63.5	60.5	58.5	55.7	55.0	55.4	58.0	61.7	65.0	66.0
Turnabout Island	25 26	119 59	66.5	65.0	64.0	60.6	58.6	55.6	54.8	55.0	58.0	62.0	65.0	66.5
Fu-tschou-fu	26 08	119 38	67.0	65.7	64.2	61.0	58.8	55.4	54.5	55.0	58.2	62.2	65.5	67.0
Wönn-tschou-fu	28 00	120 35	68.0	67.0	65.2	61.5	59.0	55.3	54.4	54.9	58.5	63.3	66.5	68.0
Itschang	30 12	111 19	69.6	67.0	65.5	61.5	59.5	54.0	53.0	54.0	58.2	63.3	67.5	70.0
Cape Yang-tze	30 50	121 52	69.8	69.0	66.5	62.0	59.0	55.1	54.4	55.0	59.5	64.0	67.8	68.8
Zikawei	31 11	121 26	69.8	69.5	66.6	62.0	59.2	55.1	54.3	54.9	59.6	64.1	68.0	69.0
Shanghai	31 14	121 29	69.8	69.5	66.6	62.0	59.2	55.1	54.3	54.9	59.6	64.1	68.0	69.0

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[1] East of Greenwich.

MEAN BAROMETER LEVELS AT THE PRINCIPAL POINTS IN THE FAR EAST—Continued.

I. METRIC SYSTEM—Continued.

Place.	North latitude.	Longitude.[1]	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	° ′	° ′												
Shaweishan	31 25	122 15	769.8	769.0	766.5	762.0	759.0	755.1	754.4	755.0	759.5	764.1	768.0	768.8
Nagasaki	32 44	129 52	66.0	65.5	64.2	61.0	58.8	55.8	56.1	56.5	58.5	62.7	65.5	66.0
Kumamoto	32 48	130 42	64.8	65.5	64.0	61.0	58.8	55.8	56.2	56.7	58.3	62.5	65.3	65.8
Saga	33 12	130 18	65.2	65.8	64.2	61.2	58.9	55.9	56.1	56.5	58.3	62.9	65.5	66.0
Fukuoka	33 35	130 23	65.2	66.0	64.6	61.2	59.0	55.9	56.2	56.4	58.2	63.0	65.8	66.2
Yamaguchi	34 11	131 27	64.7	65.8	64.5	61.4	59.1	55.8	56.2	56.7	58.2	63.0	65.5	65.8
Itsugahara	34 12	129 16	66.4	66.8	65.5	61.6	59.1	55.7	55.9	56.0	58.2	63.5	66.5	66.8
Tadotsu	34 17	133 46	63.8	65.0	63.5	61.0	59.0	56.0	56.4	57.0	58.5	62.5	65.0	65.0
Kobe	34 41	135 12	63.0	64.5	63.5	61.0	59.0	56.2	56.9	57.2	58.8	62.3	64.5	64.5
Osaka	34 42	135 31	62.8	64.3	63.5	61.0	59.0	56.2	57.1	57.3	58.8	62.2	64.5	64.4
Tsu	34 43	136 31	62.4	63.8	63.0	61.0	59.0	56.3	57.2	57.5	58.9	62.0	64.0	63.9
Hamada	34 53	132 05	64.5	66.0	64.8	61.5	59.1	55.9	56.3	56.5	58.4	63.2	66.0	65.8
Kioto	35 01	135 46	63.2	64.2	63.9	61.5	59.1	56.2	57.1	57.3	58.9	62.3	65.0	64.4
Fusan	35 05	129 06	63.8	67.0	66.0	62.0	59.2	55.7	55.8	55.8	58.0	63.9	67.0	67.0
Nagoja	35 10	136 55	62.3	63.7	63.0	61.2	59.0	56.4	57.4	57.5	59.0	62.1	64.2	63.8
Yokohama	35 26	139 39	61.0	62.5	62.0	60.8	58.8	56.8	58.0	58.0	59.0	61.8	63.0	62.4
Sakai	35 33	133 14	64.0	65.7	64.8	61.6	59.2	56.0	56.4	56.6	58.6	63.2	65.9	65.6
Tokio	35 41	139 45	62.0	62.4	62.2	60.8	58.8	56.8	58.1	58.0	59.0	61.8	63.0	62.3
Fuschiki	36 47	137 03	62.5	63.8	63.0	62.0	59.2	56.4	57.0	57.4	58.8	62.9	65.0	64.0
Chefoo	37 34	121 32	71.0	73.2	68.2	63.2	59.8	55.1	54.8	54.0	59.0	65.8	69.4	70.7
Fukuschima	37 45	140 24	60.8	62.2	63.0	61.0	59.0	56.8	57.9	58.0	58.7	62.0	63.6	62.3
Niigata	37 55	139 03	61.5	63.0	63.5	61.5	59.2	56.8	57.4	57.8	58.6	62.6	64.5	63.4
Yamagata	38 14	140 17	61.0	62.3	63.0	61.0	59.0	56.8	57.5	58.0	58.6	62.2	64.0	62.5
Ischinomaki	38 26	141 19	60.6	61.8	62.4	60.5	58.7	56.9	57.9	58.2	59.6	62.0	63.5	61.0
Akita	39 42	140 07	61.0	62.7	63.5	61.0	59.0	56.9	57.1	57.8	59.4	62.4	64.4	63.9
Aomori	40 51	140 45	60.0	62.2	63.5	61.4	59.0	57.3	57.0	57.8	58.2	62.7	64.0	62.5
Hakodate	41 46	140 44	60.0	62.2	63.5	61.4	59.0	57.2	56.9	57.7	58.1	62.1	64.0	62.5
Sapporo	43 04	141 22	58.5	61.7	61.2	60.5	58.2	57.5	56.8	57.5	57.9	61.8	62.0	61.8
Nemuro	45 20	145 35	57.3	59.8	60.0	60.5	58.2	58.0	58.2	58.6	59.4	61.3	60.2	58.9

II. ENGLISH SYSTEM.

Place.	North latitude.	Longitude.[1]	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Singapore	1 17	103 51	29.89	29.91	29.90	29.86	29.85	29.86	29.86	29.88	29.87	29.88	29.86	29.86
Sandakan	5 40	118 08	.88	.89	.82	.84	.81	.80	.82	.84	.80	.88	.78	.80
Jolo	6 03	120 59	.84	.88	.82	.85	.81	.82	.81	.84	.82	.86	.79	.80
Sigaboy	6 36	126 07	.80	.86	.83	.84	.82	.85	.80	.87	.82	.84	.80	.79
Isabela de Basilan	6 43	121 05	.84	.88	.83	.86	.82	.82	.81	.85	.83	.86	.80	.80
Zamboanga	6 54	122 08	.84	.88	.83	.86	.82	.82	.81	.85	.83	.86	.80	.80
Mati	6 56	126 14	.80	.86	.83	.84	.82	.85	.80	.87	.81	.84	.80	.79
Mount Apo	6 58	125 08	.81	.86	.83	.85	.82	.85	.80	.87	.81	.84	.80	.80
Davao	7 01	125 35	.81	.86	.83	.85	.82	.85	.80	.86	.81	.84	.80	.80
Caraga	7 15	126 30	.80	.86	.83	.84	.82	.85	.80	.87	.81	.84	.80	.80
Point Punsan	7 15	126 33	.80	.86	.83	.84	.82	.85	.80	.87	.81	.84	.80	.80
Korror	7 20	134 34	.81	.84	.86	.80	.83	.88	.80	.89	.76	.82	.78	.80
Tamontaca	7 11	124 09	.83	.88	.88	.86	.82	.84	.80	.86	.84	.86	.81	.81
Pulo Obi	8 27	104 51	.97	.94	.76	.80	.76	.74	.78	.80	.76	------	.80	.84
Tagoloan	8 33	124 40	.84	.88	.85	.87	.84	.84	.82	.86	.82	29.86	.82	.83
Dapitan	8 40	123 23	.85	.89	.85	.87	.84	.84	.82	.85	.83	.85	.82	.83
Tandag	9 02	126 10	.84	.89	.85	.87	.84	.84	.82	.82	.81	.86	.82	.83
Yap	9 29	138 05	.85	.88	.92	.85	.86	.90	.80	.90	.80	.85	.76	.84
Gigaquit	9 32	125 44	.82	.88	.85	.84	.84	.85	.80	.86	.80	.83	.82	.81
Taganaan	9 44	125 32	.84	.88	.86	.85	.84	.85	.81	.86	.80	.84	.82	.83
Surigao	9 47	125 29	.84	.88	.86	.86	.84	.85	.81	.86	.80	.84	.82	.83
Dinagat	9 58	125 35	.85	.88	.88	.86	.84	.85	.81	.86	.80	.84	.83	.84
Pulo Zapatu	9 59	109 03	.97	.95	.78	.81	.76	.75	.78	.80	.73	.86	.81	.87
Cebu	10 18	123 54	.87	.90	.88	.88	.84	.84	.83	.85	.82	.86	.83	.85
Cape St. James	10 20	107 05	.98	.96	.77	.81	.76	.74	.77	.80	.73	------	.82	.88
Carlota	10 25	123 01	.88	.91	.88	.89	.84	.83	.84	.85	.83	29.84	.83	.85
Iloilo	10 42	122 35	.89	.92	.89	.89	.84	.83	.84	.84	.83	.85	.84	.86
Saigon	10 47	106 42	.98	.96	.77	.81	.76	.72	.76	.80	.72	------	.82	.88
Cape Padaran	11 35	109 09	.98	.96	.80	.82	.80	.75	.77	.79	.72	------	.84	.88
Calbayog	12 06	124 38	.89	.91	.82	.88	.85	.85	.84	.85	.80	29.86	.84	.88
Batag	12 40	125 01	.90	.91	.91	.88	.85	.85	.84	.85	.80	.86	.85	.88
Cape Varella	12 54	109 34	.99	30.00	.80	.83	.76	.75	.76	.78	.70	.82	.84	.92
Banton	12 56	122 04	.93	29.94	.93	.90	.85	.82	.82	.84	.84	.86	.86	.90
Albay	13 09	123 42	.92	.93	.92	.89	.86	.84	.84	.84	.82	.86	.86	.90
Agaña (Island of Guam)	13 28	144 45	.94	.98	.98	.96	.91	.92	.90	.89	.94	.94	.90	.92
Tabaco	13 21	123 43	.92	.93	.92	.89	.86	.84	.84	.84	.82	.86	.86	.90
Batangas	13 45	121 03	.94	.95	.93	.91	.84	.82	.80	.82	.82	.85	.88	.92
Point Santiago	13 46	120 39	.95	.96	.93	.91	.84	.82	.80	.82	.83	.86	.88	.92
Taal	13 53	120 55	.95	.96	.93	.91	.84	.82	.84	.82	.82	.86	.88	.92
Cabra (Light-house)	13 54	120 01	.96	.96	.92	.91	.84	.82	.80	.82	.81	.86	.88	.92
Tayabas	14 01	121 34	.95	.95	.93	.91	.85	.83	.80	.82	.83	.84	.88	.92
Atimonan	14 02	121 51	.95	.95	.93	.90	.85	.83	.80	.82	.83	.84	.88	.92
Daet	14 04	122 56	.94	.94	.93	.89	.85	.84	.81	.83	.84	.86	.88	.92
Point Restinga	14 16	120 37	.96	.96	.93	.91	.84	.82	.80	.82	.81	.86	.89	.93
Santa Cruz, La Laguna	14 18	121 25	.95	.96	.93	.91	.85	.82	.80	.82	.82	.85	.88	.93
Cavite	14 29	120 55	.96	.96	.93	.91	.84	.82	.80	.82	.81	.85	.89	.93
Manila (Observatory)	14 35	120 58	.96	.96	.93	.91	.84	.82	.80	.82	.81	.85	.89	.94
Balanga	14 41	120 32	.97	.96	.92	.91	.84	.82	.80	.81	.80	.86	.89	.94
Bulacan	14 50	120 52	.97	.97	.93	.91	.84	.82	.80	.81	.80	.85	.90	.94
Bacolor	15 01	120 37	.97	.97	.93	.91	.84	.82	.79	.81	.80	.85	.90	.94
San Luis, Pampanga	15 03	120 46	.97	.97	.93	.91	.84	.82	.79	.81	.80	.85	.90	.94
Angeles	15 08	120 35	.97	.97	.93	.91	.84	.82	.79	.81	.80	.85	.90	.94
Mount Arayat	15 12	120 43	.97	.97	.93	.91	.84	.82	.79	.81	.80	.85	.90	.94

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[1] East of Greenwich.

MEAN BAROMETER LEVELS AT THE PRINCIPAL POINTS IN THE FAR EAST—Continued.

II. ENGLISH SYSTEM—Continued.

Place.	North latitude.	Longitude.[1]	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	° ′	° ′												
Iba	15 21	119 57	29.97	29.98	29.92	29.91	29.84	29.82	29.78	29.80	29.78	29.86	29.90	29.95
San Isidro	15 22	120 53	.97	.97	.93	.91	.84	.82	.79	.81	.80	.85	.90	.95
Palauig	15 27	119 53	.98	.98	.92	.91	.84	.82	.78	.80	.78	.86	.90	.95
Cabanatuan	15 29	120 56	.98	.97	.93	.91	.84	.82	.90	.81	.80	.85	.90	.95
Magalaoa	15 30	119 53	.98	.98	.92	.91	.84	.82	.78	.80	.78	.86	.90	.95
Tarlac	15 31	120 35	.98	.97	.92	.91	.84	.82	.78	.81	.79	.85	.91	.95
Bayambang	15 40	120 27	.98	.98	.92	.91	.84	.82	.78	.80	.78	.85	.91	.96
Paracel Island	16 00	111 48	30.02	30.03	.88	.86	.78	.75	.83	.76	.69	.88	.92	30.02
St. Quentin	16 00	120 50	29.98	29.98	.92	.91	.84	.81	.78	.80	.78	.85	.91	29.97
Dagupan	16 04	120 19	.98	.98	.92	.91	.84	.81	.78	.80	.77	.86	.91	.97
Sual	16 05	120 05	.98	.98	.92	.91	.84	.81	.78	.80	.77	.86	.91	.97
Santo Tomas, Union	16 18	120 22	.98	.98	.92	.91	.84	.81	.78	.80	.77	.86	.92	.97
Agoo, Union	16 20	120 21	.98	.98	.92	.91	.84	.81	.78	.80	.76	.86	.92	.97
Cape Bolinao	16 29	119 46	.98	.98	.91	.91	.83	.81	.78	.80	.76	.86	.92	.98
Naguilian	16 34	120 26	.98	.98	.92	.91	.83	.81	.78	.80	.76	.86	.92	.98
Bayombong	16 37	121 12	.98	.98	.93	.90	.84	.81	.78	.80	.78	.85	.92	.98
San Fernando, Union	16 37	120 19	.98	.98	.92	.91	.83	.81	.78	.80	.76	.86	.92	.98
Vigan	17 34	120 20	.99	.98	.91	.90	.83	.80	.77	.79	.76	.87	.93	.99
Tuguegarao	17 35	121 39	.98	.98	.93	.88	.83	.80	.78	.79	.76	.86	.93	.99
Laoag	18 13	120 34	.99	.98	.92	.90	.82	.80	.76	.78	.76	.88	.94	30.02
Aparri	18 22	121 34	.99	.99	.94	.88	.83	.80	.77	.78	.77	.88	.94	.01
Cape Bojeador	18 30	120 33	30.00	.98	.94	.90	.82	.80	.76	.77	.76	.88	.95	.02
Cape Engaño	18 35	122 05	29.99	.98	.95	.88	.83	.80	.77	.79	.78	.88	.94	.01
Hoihow	20 03	110 20	30.12	30.08	.96	.90	.80	.74	.72	.74	.72	.93	30.02	.11
San Antonio	20 22	121 55	.04	.00	.98	.90	.83	.78	.76	.77	.80	.91	.00	.05
Haiphong	20 52	106 40	.15	.10	.96	.90	.80	.72	.70	.74	.73	.92	.04	.15
St. John Island	21 40	106 36	.15	.10	30.04	.92	.80	.74	.72	.73	.77	.97	.08	.14
Gap Rock	21 49	113 59	.15	.10	.04	.92	.80	.73	.72	.73	.78	.97	.08	.14
Formosa, South Cape	21 55	120 51	.08	.04	.01	.91	.84	.77	.74	.76	.81	.94	.05	.09
Macao	22 11	113 33	.15	.11	.01	.93	.82	.74	.72	.72	.80	.97	.09	.14
Hongkong	22 18	114 12	.15	.11	.05	.93	.82	.74	.72	.72	.80	.97	.09	.14
Breaker Point	22 56	116 22	.15	.11	.05	.94	.82	.75	.72	.72	.81	.97	.09	.14
Ngan-ping	22 59	120 13	.12	.08	.04	.92	.84	.76	.74	.75	.82	.96	.09	.12
Schan-tou	23 22	116 40	.16	.13	.08	.94	.84	.75	.72	.72	.82	.98	.10	.16
Canton	23 07	113 17	.16	.12	29.94	.93	.82	.74	.72	.72	.83	.98	.10	.16
Chapel Island	24 10	118 13	.17	.14	30.08	.94	.84	.75	.72	.72	.82	30.00	.12	.17
Amoy	24 28	118 05	.18	.14	.09	.94	.85	.75	.72	.72	.83	.00	.12	.17
Okseu Island	24 59	119 28	.18	.13	.08	.94	.85	.75	.72	.72	.85	.00	.12	.17
Tamsui	25 10	121 25	.15	.10	.06	.94	.86	.75	.72	.74	.84	29.99	.12	.16
Turnabout Island	25 26	119 59	.18	.12	.08	.94	.87	.75	.72	.72	.84	30.00	.12	.18
Fu-tschou-fu	26 08	119 38	.20	.15	.09	.96	.88	.74	.70	.72	.85	.01	.14	.20
Wönn-tschou-fu	28 00	120 35	.24	.20	.13	.98	.88	.74	.70	.72	.86	.05	.18	.24
Itschang	30 12	111 19	.30	.20	.14	.98	.90	.69	.65	.69	.85	.05	.22	.32
Cape Yang-tze	30 50	121 52	.31	.28	.18	30.00	.88	.73	.70	.72	.90	.08	.23	.27
Zikawei	31 11	121 26	.31	.30	.18	.00	.89	.73	.70	.72	.91	.08	.24	.28
Shanghai	31 14	121 29	.31	.30	.18	.00	.89	.73	.70	.72	.91	.08	.24	.28
Shaweishan	31 25	122 15	.31	.28	.18	.00	.88	.73	.70	.72	.90	.08	.24	.27
Nagasaki	32 44	129 52	.16	.14	.09	29.96	.88	.76	.77	.78	.86	.03	.14	.16
Kumamoto	32 48	130 42	.11	.14	.08	.96	.88	.76	.77	.79	.86	.02	.13	.15
Saga	33 12	130 18	.13	.15	.09	.97	.88	.76	.77	.78	.86	.04	.14	.16
Fukuoka	33 35	130 23	.13	.16	.10	.97	.88	.76	.77	.78	.85	.04	.15	.17
Yamaguchi	34 11	131 27	.11	.15	.10	.98	.89	.76	.77	.79	.85	.04	.14	.15
Itsugahara	34 12	129 16	.17	.19	.14	.98	.89	.75	.76	.76	.85	.06	.18	.19
Tadotsu	34 17	133 46	.08	.12	.06	.96	.88	.76	.78	.80	.86	.02	.12	.12
Kobe	34 41	135 12	.04	.10	.06	.96	.88	.77	.80	.81	.88	.01	.10	.10
Osaka	34 42	135 31	.03	.09	.06	.96	.88	.77	.81	.82	.88	.01	.10	.10
Tsu	34 43	136 31	.02	.07	.04	.96	.88	.78	.81	.82	.88	.00	.08	.08
Hamada	34 53	132 05	.10	.16	.11	.98	.89	.76	.78	.78	.86	.05	.16	.15
Kioto	35 01	135 46	.05	.09	.08	.98	.89	.77	.81	.82	.88	.01	.12	.10
Fusan	58 05	129 06	.07	.20	.16	30.00	.89	.75	.76	.76	.84	.08	.20	.20
Nagoja	35 10	136 55	.01	.07	.04	29.97	.88	.78	.82	.82	.88	.00	.09	.07
Yokohama	35 26	139 39	29.96	.02	.00	.95	.88	.80	.84	.84	.88	29.99	.04	.02
Sakai	35 33	133 14	30.08	.15	.11	.98	.89	.76	.78	.79	.87	30.05	.15	.14
Tokio	35 41	139 45	.00	.02	.01	.95	.88	.80	.85	.84	.88	29.99	.04	.01
Fuschiki	36 47	137 03	.02	.07	.04	.96	.89	.78	.80	.82	.88	.99	.12	.08
Chefoo	37 34	121 32	.36	.44	.24	30.05	.91	.73	.72	.69	.88	30.15	.29	.34
Fukuschima	37 45	140 24	29.95	.00	.04	29.96	.88	.80	.84	.84	.87	.00	.06	.01
Niigata	37 55	139 03	.98	.04	.06	.98	.89	.80	.82	.84	.87	.02	.10	.06
Yamagata	38 14	140 17	.96	.01	.04	.96	.88	.80	.82	.84	.87	.01	.08	.02
Ischinomaki	38 26	141 19	.94	29.99	.02	.94	.87	.80	.84	.85	.91	.00	.06	29.96
Akita	39 42	140 07	.96	30.03	.06	.96	.88	.80	.81	.84	.90	.02	.10	30.07
Aomori	40 51	140 45	.92	.01	.06	.98	.88	.82	.80	.84	.85	.03	.08	.02
Hakodate	41 46	140 44	.92	.01	.06	.98	.88	.81	.80	.83	.85	.00	.08	.02
Sapporo	43 04	141 22	.86	29.99	29.97	.94	.85	.82	.80	.82	.84	29.99	.00	29.99
Nemuro	45 20	145 35	.82	.91	.92	.94	.85	.84	.85	.87	.90	.97	29.93	.88

[1] East of Greenwich.

Limit of the barometer readings in zone A in various latitudes.—Supposing that the observer is certain on the one hand of the accuracy of his barometer and on the other of the normal height corresponding to the place and time of observation, then if he possesses the baro-cyclonometer to be described in the next chapter he will proceed to adjust the aneroid thereof according to instruction there given, when the instrument will show whether he is within the region influenced by a cyclone or not. If he does not have this instrument he must decide in which division of his barometer falls the limit of the reading for zone A. This determination is of the greatest importance if the observer is a sailor, to whom it is naturally a matter of some concern to know at the earliest moment when he has entered into the body of a typhoon so as to prepare for the danger if he can not avoid it. In order to facilitate this important operation for those who have at their disposal only the ordinary barometer, we deduced from the preceding tables the limit of atmospheric pressure in zone A during the different groups of months and at various latitudes from 0° up to 50° north. The result is contained in the following table, which is substantially identical with the one given in Chapter IV of Part I, page 44, but given here for the convenience of the reader:

With regard to this table we remark the following:

(*a*) The data corresponding to the latitudes 0° to 21° north have reference to the Philippine Archipelago itself. Since for this zone the material is abundant and the variations of the barometer are of the utmost regularity, the values given are thoroughly reliable. On the contrary, the mean values derived for the latitudes 32° to 50° north do not deserve such confidence, but nevertheless they give valuable information to the observer.

(*b*) Owing to the influence of the continent of Asia, more important differences appear between places situated in the interior or on the coast of the continent and on the islands farther distant from it, as, for instance, between Nagasaki and Shanghai, although the latitudes of the places differ but little. The difference of the mean barometer levels is still greater between Chefoo, Fukuschima, and Tokio, which lie nearly on the same parallel, though they vary in longitude as Fukuschima is some 19 degrees distant from the eastern coast of China. We must remember that, commencing with the Balingtan Channel, during the months of the first group the barometer levels in the ports of the Chinese coast are higher than at more eastern points situated in the same or near latitudes.

Thus, for example, they are higher in the Chinese ports of the Yellow Sea than in the southern and central part of Japan, so that the difference in February between Chefoo and Niigata is 10.2 millimeters (0.4 inches), and a similar difference exists between the coast of Korea and Manchuria and the northern part of Japan. The mean values which we give for the latitudes can therefore be only approximate values of a purely practical signification. Their purpose is to put the observer on his guard whenever there is any probability of an atmospheric disturbance. The difference in the barometer readings is not so great in the months of the second group. In the months of the third group the conditions that prevailed during the first group are inverted—that is, the pressure on the east coast of Asia is less, but the differences which appear are not so great as is the case in the months of the first group. It follows from this that for latitudes above 21° north the barometer levels occurring in zone A, the outermost zone of the cyclone, represent only approximate values for the months of the first group, but that they are sufficiently accurate for the months of the second and third groups. These differences chiefly show themselves north of the Balingtan Channel, as can be seen by consulting the charts of isobars given in Chapter IV of Part I. Hence the mariner can safely use the values which we give for the zone comprised between 0° and 20° north when navigating the Pacific Ocean between the Philippines and the Eastern Carolinas.

(*c*) The values of the following table are, therefore, applicable to the Philippines, the south China Sea, the Pacific Ocean south of latitude 20° north, to the Formosa Channel and the adjacent seas, the Yellow Sea and the neighboring coasts, to Japan and the adjacent oceans, to Korea, and the coast of Manchuria.

HEIGHT OF BAROMETER CORRESPONDING TO THE OUTER LIMIT OF ZONE A OF A CYCLONE.

Between parallels—	Inches.	Millimeters.	Season.
0°–11° N.	29.76	756	Throughout the year.
11°–17° N.	29.76	756	During months of first group.
	29.73	755	During months of second and third groups.
17°–21° N.	29.80	757	During months of first group.
	29.76	756	During months of second group.
	29.73	755	During months of third group.
21°–25° N.	29.92	760	During months of first group.
	29.80	757	During months of second group.
	29.65	753	During months of third group.
25°–32° N.	30.12	765	During months of first group.
	30.00	762	During October and November.
	29.84	758	During April and May.
	29.65	753	During months of third group.
32°–35° N.	30.04	763	During months of first group.
	29.84	758	During months of second group.
	29.69	754	During months of third group.
35°–40° N.	29.96	761	During months of first group.
	29.80	757	During months of second group.
	29.69	754	During months of third group.
40°–50° N.	29.76	756	Throughout the year.

Regarding the use of the foregoing table we must add:

(1) The limiting months of two consecutive groups exhibit characteristics of both groups—that is, May and June, November and December, March and April, September and October, as we have already pointed out in Chapter II of Part I.

(2) The same may be said of the parallels of latitude adjacent to the limits of above zones—that is, 10°–12°, 31°–33°, etc.

(3) The barometer readings have reference to the lowest reading occurring during the day and accordingly either to the morning or the afternoon minimum.

(4) Whenever the barometer at the time of the daily minimum falls as far as the tabular value corresponding to the place of observation and the time of the year, the observer may be reasonably sure of the presence of an atmospheric disturbance, but he will not be able to tell whether the storm will burst over his location or not unless he is acquainted with the characteristic barometric movements of the region. In speaking of zone A in the first part of this book we said that the diurnal and nocturnal oscillations are not completely lost, but only modified. It is on this knowledge that the observer has to found his prevision of the danger into which he may be running, as well as the probability of avoiding it.

Normal diurnal and nocturnal oscillations of the barometer.—We can not do better than quote what Fr. Faura wrote in his valuable pamphlet, "Señales Precursoras de Temporal en el Archipiélago Filipino." He says:

> The barometer in these latitudes presents two very regular daily oscillations, whenever it is not influenced by an atmospheric disturbance.
>
> (1) The barometer rises from 4 a. m. to 9 or 10 a. m. The amount it ought to rise in order to indicate that the weather will continue settled for some time is 2.5 to 3 millimeters.
>
> (2) From 9 or 10 a. m. until 3 or 4 p. m. the barometer falls, but during the hot season it sometimes continues to fall till 5 o'clock p. m. The amount of the descent is generally equal to the rise in the morning. If this is the case and the fall does not exceed 3 millimeters the observer may rest assured that the weather will remain settled for some time.
>
> (3) After 3 or 4 o'clock p. m. (respectively 5 p. m. during the hot months) the barometer rises again until 9.45 or 10 p. m. The normal amount of this rise is never equal to that of the morning rise, but oscillates between the values 2 and 2.5 millimeters. If the barometer rises the indicated amount we may likewise be confident that the fine weather will last.
>
> (4) The barometer falls again between 10 p. m. and 4 a. m. of the following day. The range of this move-

ment does not exceed 2.5 millimeters. A rise of between 2–2.5 millimeters assures us that the weather will continue without great changes.

(5) The weather assumes a doubtful character the moment a change takes place in these oscillations in the sense of a diminution of pressure—that is, if the barometer either does not rise as far as it should, or falls lower than it ought to do under normal conditions.

For an illustration of the preceding remarks of Fr. Faura we refer the reader to the table contained in Chapter IV of Part I, page 39, which exhibits the daily march of the barometer at Manila.

Changes of the barometric curve during cyclones.—The changes in the barometric curve may take place in four different ways. In two of them a total alteration is effected, while the two other result in only a partial change. A total change occurs when the barometer either falls or remains stationary at the time of normal rising. It is clear that in both cases the curve will be entirely changed. The partial changes result if the barometer either does not rise as much as it ought to do, without afterwards falling below the normal minimum, or if after an abnormally small rise it descends below the normal level for the time of minimum. In either case the curve is indeed changed, but the daily oscillations are not entirely obliterated. These four changes of the barometric movement indicate four different relations between the cyclonic vortex and the place of observation, and correspond to four absolute movements of the vortex which we are going to explain, commencing with the least dangerous.

The first partial change.—If the barometer at the time of the usual rise, from 4 to 9 a. m. and from 3 or 4 to 10 p. m., rises but little (much less than is required by the atmospheric wave at the place of observation) and, on the other hand, at the time of the fall it does not fall the normal amount, so that the last minimum is not lower than the preceding, we must take this for a sign that the cyclone is still far off and is advancing slowly, without the observer leaving zone A, or that the distant center remains either entirely or nearly stationary, without any change of zone A at the place of observation. In this case the amplitude of the barometric curve is less than usual. This kind of barometer movement is observed in the southern part of the Archipelago, from parallel 4° to that of 10° north, during the months of the third and second groups, whenever a center crosses higher latitudes or when it recurves in the Pacific, or when it, especially in June and July, remains stationary not far from the northeast and northwest coasts of Luzon. In the latter case squalls of rain and wind come from the third quadrant, and they last occasionally for several days. They correspond to a condition of weather which the natives call "colla."

In Luzon and the northern part of the Visayas such movements of the barometer are also noticed during the months of the first group, although not so frequently, whenever a cyclone crosses the southern part of the Archipelago. Northerly winds then usually set in, being mostly accompanied by heavy rains on the east coast, sometimes extending as far as the west coast.

The second partial change.—This occurs when the barometer does not rise as much as it should according to the daily oscillation, and when after it has risen it falls still farther than should be the case, so that each subsequent minimum is lower than the preceding. In this case the cyclone is approaching the observer in some way or other.

We say "is approaching in some way or other," because the place of observation may be (1) at various points on the radii of zone A and partly of zone B. In this case the barometer will fall below the limit value which divides the two zones, and subsequently a total change of the curve will take place, of which we shall treat further on. (2) It may be successively at various points along a chord of zone A or B. In this case the oscillation can be traced in the curve, and no total change will follow. (3) It may occupy positions which are intermediate between the two named—that is, when the trajectory curves—and accordingly as the radial or tangential direction prevails the daily oscillation will disappear or be maintained.

In all three cases we may observe common characteristics, so long as the station lies within zone A or within the outer regions of zone B. First a fine rain appears, and next come squalls more or less intermittent, the force of the winds increases until they attain the strength of gales.

In the first case the oscillation becomes gradually obliterated, and the phenomena which are characteristic of total change appear.

In the second case the barometer usually falls until it has reached the limiting value between the zones A and B. This gradual descent lasts occasionally for several days over the Archipelago and the adjacent seas; then the winds from the third quadrant freshen up in the central and southern parts of the Archipelago, and the barometer having reached its minimum commences to rise slowly. The center passes either rapidly and the squalls of rain and wind follow each other quickly or else it moves slowly, the frequency of the squalls being more moderate, or else the storm recurves and its effects may still be felt for some days, or, finally, the center remains almost stationary and for several days wind and rain continue. The effects of the slow transit, of recurvature, or the cessation of advance of a cyclone are not different from a "colla," which, as we have seen, accompanies the first kind of partial change. In such cases the amplitude of the oscillations usually does not differ much from its normal value; the curve *aa* on Plate I was traced under such conditions.

If the third supposition as to the successive positions of the observer within the storm field is verified the case will belong to this class if the daily oscillation does not disappear; otherwise, it will be one of the two cases of total change.

As constant experience teaches, this second class of partial changes is independent of the barometric height corresponding to the limiting zone of the storm and depends exclusively upon the normal pressure at the place of observation. It consequently is one of the most valuable warnings of the existence of a cyclone. In some instances it even amounts to a strictly precursory sign. For it has repeatedly happened that the barometer having been normal for some time, there commenced a slow descent of such nature that the successive minima gradually became lower and lower until they reached the limit of the cyclonic isobar, and then finally occurred a pronounced change corresponding to one of the three cases which we have just discussed. An observer, therefore, who carefully watched the changes of his barometer and noticed the gradual increase of the differences of pressure from day to day could recognize the probability of danger one or two days before the barometer reached the limit—that is, about three days before the storm burst over the locality. This holds good at least in the first and third cases spoken of. In the third part of this work the reader will find a practical instance of this kind. (See Chapter III, Part III.)

Total change—Case 1.—If the barometrical curve shows an inversion—that is, if the barometer falls instead of rising—the approach of the cyclone is certain, and the place lies somewhere between zones A and D—that is, the center of the storm will either pass over the place or at least very close to it.

The barographic curve will consequently take one of the forms shown on Plate I. It will resemble curve *bb* if only the innermost part of zone B traverses the place of observation; should also zone C reach the place, the curve will take the form *cc*; while the passage of zone D produces a curve like *dd*. This total alteration hardly ever takes place unless the barometric level has descended below the division corresponding to zone A, whence we infer that this change is ordinarily not observed unless one of the partial changes described above has preceded.

Total change—Case 2.—If the barometer remains stationary instead of rising, after having fallen below the inferior limit of zone A, this is usually a sign that the place will successively be on a chord intersecting zone B or zones C and D, though it may also be an indication that the place will be in the center of a cyclone which is not fully developed, or one with a small gradient. We observe these changes more frequently in the lower latitudes of the Pacific Ocean, where are found the zones of origin of cyclones, sometimes also in Mindanao and the Visayas as well as in the adjacent seas, when cyclones are developing near the Archipelago.

All these changes have reference to the time of the normal barometrical rise, but there are also some which occur at the time of its fall, and these are by their very nature exceedingly difficult to explain, as we shall see.

We reproduce here only what Fr. Faura says in the publication already mentioned[1] about these changes:

"In order to deduce the existence of a typhoon, not from the behavior of the barometer during the hours of rise as has hitherto been done, but from its changes during the hours of descent—that is, during the time from 9 or 10 o'clock a. m. to 3 or 4 o'clock p. m., and again between 10 p. m. and 4 a. m. of the next day, it is necessary to exercise great caution, because changes may occur which are likely to confuse the observer. If the barometer falls more than 3 millimeters (0.12 inch) there is no doubt that a disturbance exists, but we can not ascertain the character of this disturbance. If the fall is greater than 4 millimeters (0.16 inch) it is always owing to a cyclone, but even then we can not say whether it will touch the place or not. We must watch the rate of the fall, and if it is more than 1 millimeter (0.04 inch) per hour we have no time to lose, for the cyclone is approaching and in a few hours will bring all its force into play. If the fall is less than 1 millimeter (0.04 inch) per hour we may hope that there is time enough to wait for the rise so as to derive from it with tolerable probability, in accordance with the rules which have been given, what we may expect in the future." These rules have a practical application only when the barometer is below its normal level, but not when it is normal or high, because in the latter case a fall of 3.5 millimeters (0.14 inch) or even of 4 millimeters (0.16 inch), may occur without the existence of the slightest atmospheric disturbance. We have combined in a table a number of cases in which an unusual fall of the barometer occurred at a time of high atmospheric pressure, adding the most important meteorological elements, so as to fix the conditions under which such a fall may be observed. We have taken only the first few months of the year 1897.

We find the greatest absolute variation of the barometer on the 14th of April, the variation of temperature being only very slight. In order to explain this we must remark that the horizon was covered with rain clouds on this day, especially in the second quadrant, and that nimbi were coming up, producing violent showers of rain; at Manila the sun was shining for only six and a half hours.

The day before the absolute and relative humidity had been very low, the sun shining for eleven hours and thirty-five minutes. The minimum of the absolute humidity on April 13 was 12.7 millimeters (0.50 inch), and that of the relative humidity 35.5 per cent.

Month and day.	Fall of the barometer.	Variation of the thermometer.	Humidity.		Evaporation.	Sunshine.		Barometer.	
			Absolute.	Relative.				Maximum.	Normal.
	Mm.	°*C.*	*Mm.*	*Per ct.*	*Mm.*	*h.*	*m.*	*Mm.*	*Mm.*
Jan. 9	3.64	12.5	13.2	45.0	7.5	10	40	762.84	761.36
Jan. 11	3.71	10.9	15.6	50.0	8.0	10	20	61.91	
Jan. 25	3.66	11.4	13.5	[1]41.0	[2]8.3	10	10	64.46	
Jan. 26	3.95	9.8	17.2	54.0	7.5	10	20	63.71	
Feb. 8	3.67	9.6	18.6	48.0	10.0	10	10	62.77	761.73
Feb. 15	3.81	11.9	14.6	56.0	7.9	10	50	63.40	
Feb. 22	4.10	12.1	16.5	52.0	7.5	11	20	63.20	
Feb. 25	4.20	11.4			10.5	10	30	61.87	
Mar. 13	4.10	13.2	[3]9.9	[3]31.5	12.8	10	5	63.39	760.86
Mar. 14	4.14	13.4	11.3	35.0	11.3	11	15	63.00	
Mar. 18	4.15	10.9	16.7	43.0	9.6	11	35	61.31	
Apr. 12	4.03	9.4	15.4	[4]46.0	13.2	11	00	61.53	759.69
Apr. 14	4.23	8.1	17.6	48.0	19.7	6	30	[2]63.10	
Apr. 11	3.73	10.9	18.5	45.0	10.3	11	40	60.18	758.53
May 12	3.68	10.9	19.7	52.0	10.5	11	40	60.92	
May 13	3.68	10.6	20.1	54.0	10.4	11	20	60.98	
May 26	3.83	10.1	19.7	56.0	9.8	10	00	59.92	

[1] Minimum of the month.
[2] Maximum of the month.
[3] Absolute minimum since the foundation of the Observatory.
[4] The driest day of the month; the maximum of the relative humidity amounted to only 78 per cent.

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[1] "Señales Precursoras de Temporal en el Archipiélago Filipino," p. 31.

We have taken into consideration those cases only in which the fall of the barometer was greater than 3.5 millimeters (0.14 inch); this happened:

(1) On cloudless days, when the sun was shining for more than ten hours.[1]
(2) On days on which there was a great variation of temperature.
(3) On relatively dry days.
(4) On days with great evaporation.
(5) On days with slight vapor tension.
(6) On days on which the barometer stood above its normal level.

Hence it follows that it will not be difficult for the observer to decide whether or not an observed extraordinary fall of the barometer should cause him anxiety. A fall which leaves him in doubt or which looks suspicious will, however, but rarely occur, unless a partial change of the oscillation has preceded it, and hence this rule will not have many practical applications. Still it is well worth knowing.

WORKS WHICH MAY BE CONSULTED IN CONNECTION WITH CHAPTER V.

Carrasco, F. La Previsión del Tiempo ó Medio de Prever la Dirección y Fuerza del Viento por Medio del Barómetro, Termómetro y Psycrómetro. Madrid, 1867.
Chevalier, Rev. S., S. J. Essay on the Winter Storms on the Coast of China. Shanghai, 1895.
Faura, Rev. F., S. J. Señales Precursoras de Temporal en el Archipiélago Filipino.

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[1] With the exception of April 14, for reasons already mentioned.

CHAPTER VI. THE BAROCYCLONOMETER.

Although it can not be denied that there exists a certain relation between the height of the barometer and the distance of the vortex, according to what we have said in the preceding chapter, still the reading of the barometer does not give us any information with regard to the direction of the vortex, information which is frequently of the greatest importance to an observer. Fortunately, we can obtain this from the laws given in Chapter III. Hence it follows that if by combining the principal deductions of both chapters we could reduce them to practice by means of a simple mechanical instrument, we would have an efficacious means of reassuring us at the first signs of a typhoon. This has been our aim in inventing the apparatus which we have called the "barocyclonometer." The present chapter deals with the description of the instrument and the scientific principles on which each part of it is based, leaving for the next the use and management thereof.

Necessity of such an instrument.—In the preface of a descriptive pamphlet on the barocyclonometer published by this Observatory in 1898 I wrote:

> Two reasons mainly induced me to procure the construction of the new apparatus which is described in this pamphlet. The first was the great convenience, not to say necessity, of a barometer which could be used indiscriminately in all the latitudes of the Far East, especially now that the exigencies of traffic and commerce on the one hand, and the manifold complications of an international character on the other, open each day new courses to the frequent navigation of our mariners of the Navy as well as of the merchant marine. Moreover, since in these seas the meteorological elements present such different characteristics that the navigator sometimes in a single voyage finds normal barometric heights as diverse as 754 and 758 millimeters in the short distance which separates Hongkong from Manila, and 771 and 759 millimeters between Chefoo and Iloilo, it is quite impossible in these cases to apply the fixed readings which are commonly engraved on the faces of barometers. Even the best of them have this defect, as, for instance, the barometer of Father Faura, which consequently is applicable only to the limited zone of our Archipelago. Add to this that in the seas of this Far East the barometric height limit of the outermost zone of the typhoons, a datum of capital importance, fluctuates between very different values, being 765 millimeters for the twenty-fifth to the thirty-second parallels of north latitude, and 756 millimeters for the tenth to the sixteenth parallels of north latitude during the winter months. For which reason it is impossible for the mariner to navigate securely and to forestall the danger of such terrible meteors by using a "common reading" in seas where the extreme barometric heights of the body of the cyclone differ normally more than 8 millimeters. How this difficulty has been obviated in the aneroid the reader will see in the course of this work.
>
> The other reason, of no less weight, is the sad fact that the growing popularity of Father Faura's barometer has induced some manufacturing firms to imitate said aneroids, but—in order to profitably meet industrial competition—in such a way that frequently the observer, instead of finding in them an accurate and trustworthy instrument, as would be right, finds in his possession a mere hardware toy which would be capable of discrediting Father Faura's good arrangement of the indications and readings engraved on the face thereof, if its fame were not so justly established. Several times we have heard Father Faura lament this pernicious abuse, which, unfortunately, has no remedy. Now that the advisability is recognized of offering to the public a new apparatus which, on account of being universal, may be used also in other latitudes than those of our Archipelago, we shall from the very beginning make sure of the most important point, which is the fidelity of the instrument, so that persons who wish to have the quality of their barometer guaranteed can have it.[1]

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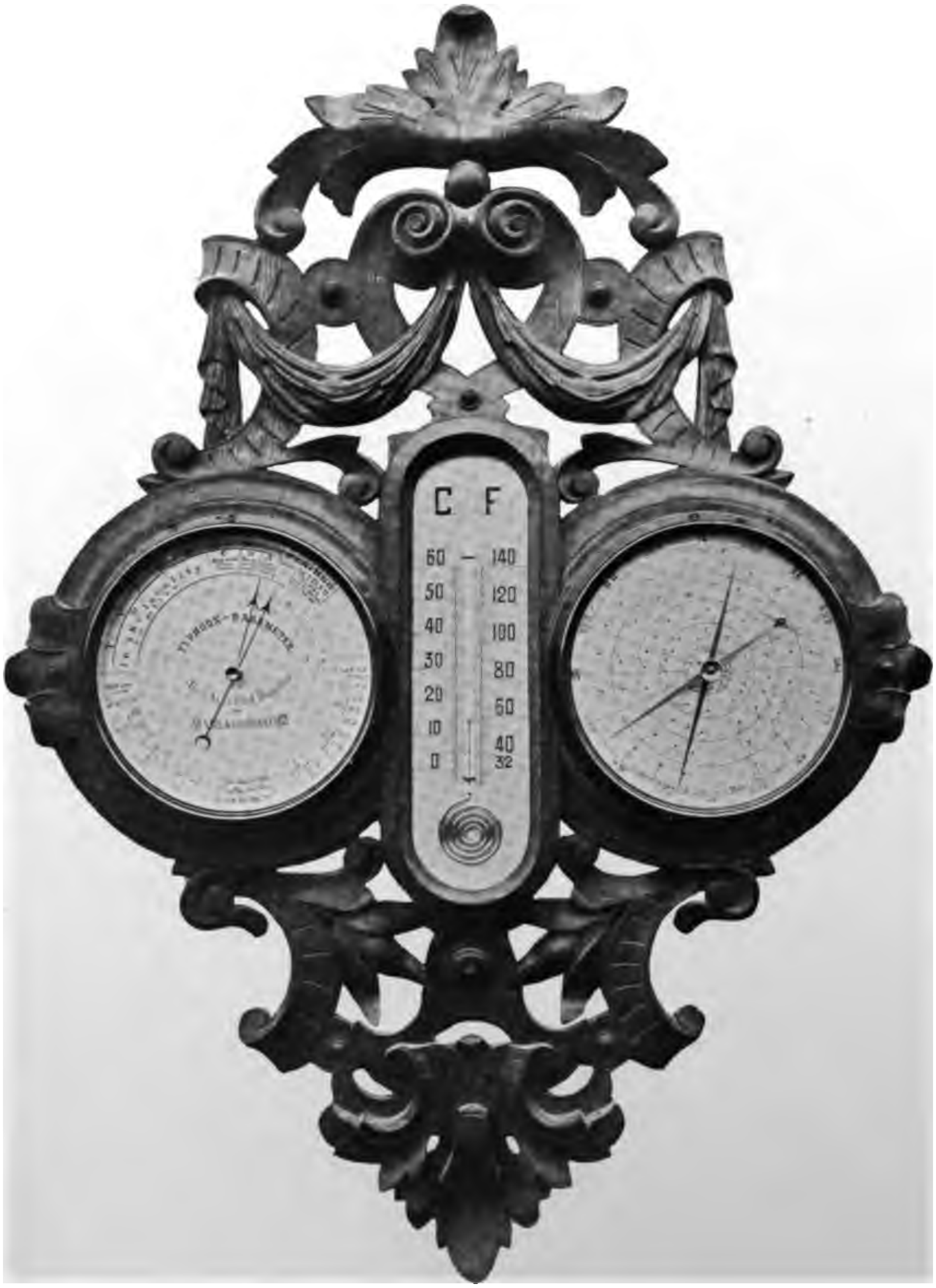
[1] The construction of this instrument has been intrusted to the firm G. Lufft, of Stuttgart. The barometer and the cyclonometer are also constructed separately, in order that those who use Father Faura's barometer, which is so popular in this Archipelago, may complete it without great expense by simply procuring the cyclonometer.

Plate XXXVII.



THE BAROCYCLONOMETER.

UNIV. OF MICH.

Above reasons refer exclusively to the aneroid of the new apparatus. Touching the cyclonometer, it is superfluous to enlarge on the practical advantages which the mariner may derive from it, principally in his voyages on the high seas. Whoever reads this pamphlet may judge for himself of it. All we claim is to offer him, as it were, a guide, simplifying the apparatus so that he can manage it even in cases when the manifold attentions to diverse maneuvers and the anxiety and confusion which usually accompany the imminence of danger do not permit complicated calculations.

The first of the reasons mentioned above is to-day certainly stronger than ever before. For, since these Islands have come into the possession of the United States of America, navigation on the seas to the north and east of Luzon has vastly increased, and consequently an instrument which to the merit of Father Faura's barometer adds the incomparable advantage of being applicable with the greatest facility to different latitudes throughout the Far East must be highly appreciated by mariners.

The documents requesting from the Spanish Government the privilege of importation and patent of the instrument for the Philippines were lost, owing to the disturbances in this Archipelago. Imitations of the instrument can not therefore be now legally prevented. It has been constructed in London and in Germany, the indications on the rim having been translated into German.

The barocyclonometer (Pl. XXXVII)[1].—As its name suggests, the barocyclonometer is a combination of a barometer and of a novel contrivance which we have named cyclonometer. As the instrument is actually constructed it also comprises a thermometer, showing the temperature in both Fahrenheit and Centigrade degrees, but, although this addition augments the convenience of the apparatus, it is none of its essential parts.

I. The aneroid barometer (Pl. XXXVIII.)—The barometer, which if it is to meet requirements must be a first-class instrument, has some remote resemblance to the barometer of Fr. Faura, on which it is based, but differs from it in several important points. The face of the aneroid exhibits the double graduation corresponding to the millimeter and the inch scale, respectively, of the mercurial barometer. Around this face is laid a flat ring of silvered brass about 23 millimeters wide, which, being attached to the rim that holds the cover glass, can be made to revolve around the dial by turning said rim. The divisions and legends engraved upon this ring bear no relation to definite lines of the graduation. Those of the upper half, however, correspond to the groups "fair weather," "change," "unsteady," or "stormy weather" of the ordinary aneroid for popular use, while the fact that the ring can be turned about the center of the face constitutes the adaptability of this barometer to different latitudes and to the various seasons of the year. The data necessary for effecting this adjustment are engraved on the lower half of the ring itself.

(1) **The first group.**—"Fair weather," "settled" occupies a considerable portion of the first quadrant, its limits toward the right being as vaguely defined as those of the group "unsettled" or "stormy"—"typhoon" toward the left. Since for the Philippines the lower limit of pressure during variable weather lies between 755 and 756 millimeters (29.73 and 29.76 inches) and the width of this group is 4 millimeters (0.15 inch), the lower limit indicating "fair weather" will vary between 759 and 760 millimeters (29.88 and 29.91 inches). The group "fair weather" is automatically determined by setting the index for variable weather as will be explained forthwith. (See 2.) This division also gives the directions of the winds which usually prevail when the barometer needle indicates high pressure—that is, north to east in December, January, and February, and east to south during March and April. The northeasterly winds commence already in November. In February they draw more to the eastward, while in March and April we have southeasterly winds. Experience teaches us that they are all the steadier the higher the needle points. The north to east winds of the period November to February drive to the eastern coast of Luzon masses of clouds from the ocean, where they have been formed in consequence of the ascending air currents during the daytime. These clouds condense and are the source of rain on the east coast, which is all the more copious the steadier the winds remain. Occasionally it happens that the

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[1] **Another form of the barocyclonometer (aneroid and cyclonometer in separate boxes) is shown on Plates XXXVIII and XXXIX. In this case the barometer is inserted on the face of the aneroid.**

cloud masses are driven across the whole island, and in such cases they bring heavy rains over the west coast also. But these are exceptions; there usually prevails at this time of the year fine and dry weather on the west coast of Luzon and in the greater part of the interior of the Archipelago.

(2) **The second group.**—"Variable," having, as stated, a range of 4 millimeters (0.15 inch), corresponds to "changeable" of the ordinary barometer, and needs no explanation. This division comprises the normal barometric readings for the months from May to October. The hand of the aneroid will also recede to it whenever a cyclone is more than 500 nautical miles distant and consequently still very far off. As the months May to October show a great tendency for atmospheric disturbances, the weather is unsteady or changeable if the needle moves in this division.

With northerly winds the weather is always unreliable, whatever may be the time of the year, as soon as the needle enters this group, except perhaps during October. The reason for this is that during the months from May to September northerly winds are abnormal for the region of the Philippines, and hence indicate abnormal conditions of the atmosphere, while from November to April this whole section of the barometric scale lies below the normal level of the barometer.

Adjustment of the barometer.—Special attention is called to the limit of this second group toward the left, which is marked by a red line or arrow and serves as index for adapting the instrument to latitude and season, as previously stated. It may also be used to correct the weather indications for elevation above the level of the sea.

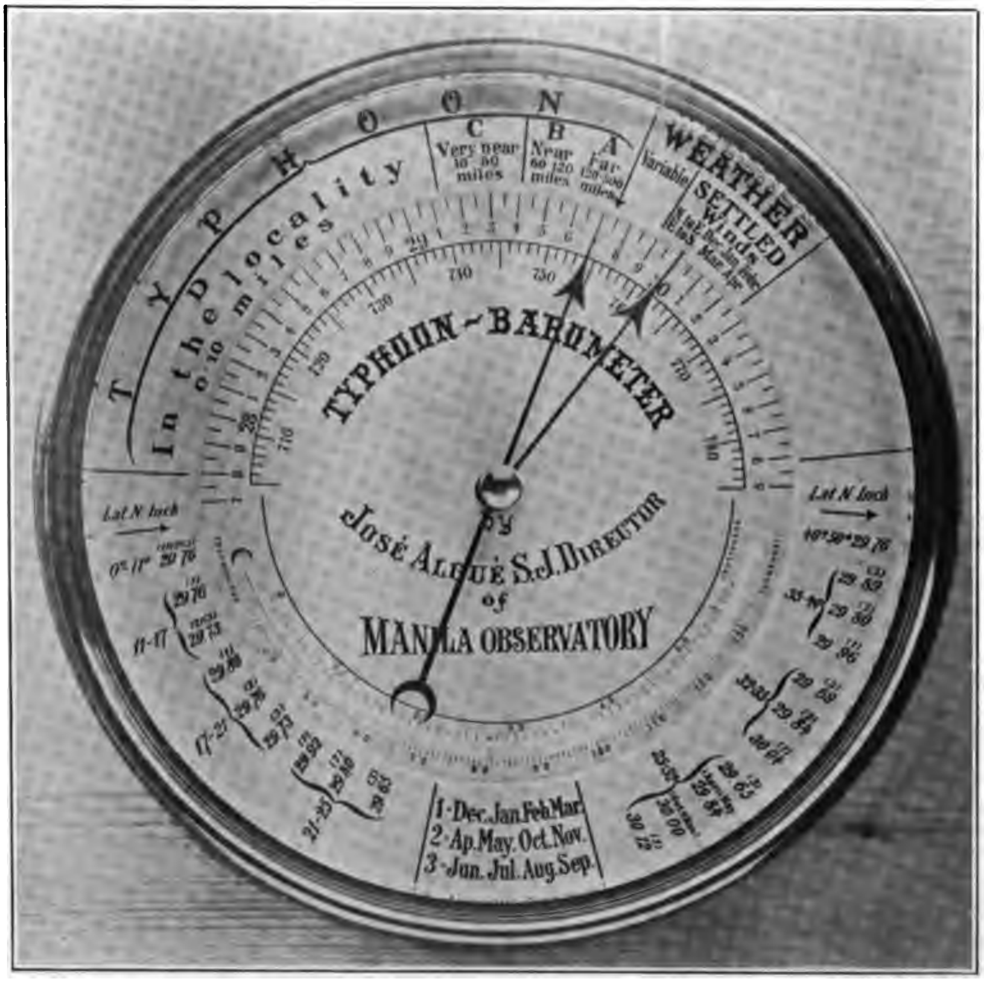
As has been remarked in Chapter V (p. 133), the mean barometric readings at the outskirts of a typhoon or, in other words, the upper limits of atmospheric pressure for "stormy weather," differ not only for different latitudes but in the majority of instances also for the same parallel during the various groups of months into which we have divided the year.

These variations, ascertained by long experience and not inconsiderable comparative study, we have laid down in the table given in Chapter V (p. 135). But for the convenience of the observer they are also engraved on the lower half of the movable ring surrounding the face of the aneroid. In the lowest section of the annular sector are found the months constituting the groups 1, 2, 3. To the right and left of it are given the different zone limits and the corresponding barometer readings for the various groups—e. g., 0°–11°, $\overset{1)2)3)}{29.76}$ (inches), $\overset{1)2)3)}{756}$ (millimeters), reads: "In the zone bounded by the equator and the eleventh parallel of north latitude the mean atmospheric pressure at the outskirts of a typhoon is 29.76 inches (756 millimeters) throughout the year." In the zone included between the eleventh and seventeenth degrees of north latitude the same limit will be seen to be 29.76 inches (756 millimeters) for the first group and 29.73 inches (755 millimeters) for groups 2 and 3, while for the zone 25°–32° north latitude there is not only a different value assigned for each group, but two different values for group 2, one for April and May, the other for October and November. Thus it is seen that the whole of the table given on page 135 is given on the instrument.

The process of adaptation is best shown by an example. Suppose a captain finds that on May 15, at a given instant, the ship's place is 7^h 46.4^m east and 18° 3′ north. Turning to his aneroid, he finds 29.76 inches (756 millimeters) to be the mean upper limit of pressure indicating stormy weather in his latitude and month (group 2). He will now turn the ring until the red arrow, above spoken of, points to 29.76 inches, and his barometer is adjusted as far as weather indications are concerned. The farther the needle points to the right of the red index, so much the steadier the weather will be. But should, after adjustment, the needle either constantly or at least at the hours of minimum point to the left, the ship has entered the outermost zone of a typhoon.

The same arrangement serves also to correct the indications for elevation of the instrument above sea level, etc. The graduations corresponding to the heights of the mercurial column at 0° C. (32° F.) and the level of the sea, any considerable elevation of the barometer above said level can not be neglected. Unless great heights are in question we may assume that the decrease of atmospheric pressure is roughly 0.01 inch for every 10 feet (or about 1 millimeter per 11

Plate XXXVIII.



THE BAROMETER OF THE BAROCYCLONOMETER.

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meters) elevation. This amount is therefore to be subtracted from the tabular reading and the index arrow set accordingly. On board ship the elevation can never give rise to great errors, but the case may be very different with instruments installed on land. Unless the elevation is small the corresponding correction should be ascertained and applied. If this precaution were neglected a barocyclonometer at an elevation of 800 feet might cause considerable alarm by indicating a typhoon in close proximity (10 to 60 miles), when it should promise settled fair weather.

(3) **Third group—"Typhoon."**—This group corresponds to "stormy weather" of the ordinary aneroid, because, the barometer being adjusted according to directions just given, the needle never moves into this section unless the instrument is under the influence of a typhoon less than 500 nautical miles distant. This section, the largest of all, is subdivided so as to make its parts correspond to the atmospheric pressures prevalent in the four zones, into which, as mentioned before, we consider the horizontal section of the lower portion of the typhoon divided. The corresponding divisions are lettered in accordance with these zones A, B, C, and D. (See Pl. I.)

Zone A—Typhoon distant.—If the needle has reached this division and the barometer shows an inclination to fall we may be tolerably certain that the center of a typhoon is between 500 and 120 miles distant. The width of this zone is 4 millimeters (0.16 inch).

Zone B—Typhoon near.—The needle moving in this division indicates that most probably there is a cyclonic vortex somewhere at a distance varying between 120 and 60 miles. The range of pressure for this zone is, like that of the preceding, 4 millimeters (0.16 inch).

Zone C—Typhoon very near.—When the needle reaches this division, which has a range of 7 millimeters (0.28 inch), it is a sign that the center of the typhoon has approached to within 60–10 miles. A careful study of the minima recorded during the passage of more than 280 cyclones makes it almost certain that the vortex will have arrived at less than 60 miles distance from Manila when the barometer has fallen to 747 millimeters (29.41 inches) at the time of the daily minimum.

Zone D—Typhoon at the place of observation.—Distance of the center, 10–0 miles. Having carefully noted the barometric minima at the passage of typhoons over a place or very close to it, we have observed that in almost every instance the upper limit of atmospheric pressure is 740 millimeters (29.134 inches). Toward the left, however, this division is undefined, though the barometer very rarely falls below 700 millimeters (27.56 inches).

Before we conclude the description of this portion of the barocyclonometer we must call attention to the following important points:

(*a*) The bearing of the center and the direction of its progressive movement can not be ascertained from the observations of the barometer alone; they must be determined by means of the laws of cyclonic movements, previously explained.

(*b*) Nor does the barometric height as such give us any clue as to the force of the wind or the violence which the cyclone is likely to develop. The intensity of a cyclone depends in the main on the barometric gradient, and the latter, in turn, is not dependent on the absolute amount of pressure, but on the rapidity with which it diminishes, as is evident from the definition of barometric gradient and has been proven by experience. The inclination of the cyclone axis, which also has no connection with the barometer level, has a very great influence upon the force of the wind.

(*c*) Once more we repeat, that the aneroid must be of the very best quality to be of service. We have found on board ships instruments of a very poor class, which are of no use whatever. To make sure of the quality of the aneroid it ought to be compared for some time with a standard barometer. But even after its excellence has thus been established before the apparatus was set up, this comparison should be repeated at least once a year, especially after the aneroid has been exposed to very great oscillations—e. g., in passing through the vortex of a cyclone. In this case the comparison should be made as soon as practicable. These investigations are best instituted at one of the large observatories of the Far East—e. g., Hongkong, Shanghai, Tokio, Manila—whose directors will, no doubt, willingly lend their aid.

(*d*) It is very important to have a clear idea of what is meant by *normal barometric height*.

The normal barometric height of a place is the *mean* of the barometer readings made at that place during a given period of time, reduced to sea level and to 0° C. (32° F.), also corrected, if one wishes, for the effect of gravity. Where the range of pressure is small, as is the case in the Tropics, it is convenient to group the months together, and, taking the mean of all the readings of each group, deduce therefrom the normal barometric level for the respective groups. Where, however, the annual variation is considerable, it will be necessary to find from the respective monthly means the normal atmospheric pressure for each month.

The normal barometric height, therefore, varies (1) with the various seasons of the year, (2) with latitude, and (3) with the geodetic position.[1] Hence it is also easily understood that the standard value 760 millimeters is very improperly termed the *general normal height of the barometer at the level of the sea,* since the pressure at sea level is necessarily different at places differently situated, and even at one and the same place varies with the seasons.

From the preceding remarks we can draw the following conclusions, which are paramount in meteorology:

(1) According to the very nature of normal barometric height, this furnishes us the only correct point of reference from which to estimate high and low barometers. For instance, for certain points of the interior of Siberia the monthly mean for January, corrected for elevation and temperature, gives as normal barometric height for this month 774 millimeters (30.472 inches). Consequently, at these places the barometer has to be called *low* if at the time of the diurnal maximum it indicates a pressure of 773 millimeters (30.433 inches), although this level is rather high if compared with the conventional value of 760 millimeters.

Whenever, therefore, the needle oscillates about the point of reference—that is, about the normal barometric height of the place of observation for the season in which the reading is made—it is not possible to say whether the weather will improve or become worse. The weather is *variable* because the *normal barometric height of the place and time, and not 760 millimeters, is the barometer level indicative of variable weather.*

(2) Supposing, for example, that at a given point the normal barometric height is 769 millimeters, it is perfectly absurd to say that this barometric level is 9 millimeters higher than the normal barometric height at sea level for this place. The reason is that the idea of normal barometric height essentially includes that the barometer means be reduced to the level of the sea.

II. The cyclonometer or wind disk.—The cyclonometer resembles the aneroid in shape and dimensions, but is, of course, an entirely different instrument. (See Pl. XXXIX.)

The face plate of the cyclonometer, which is immovable, has a circular recess of a radius somewhat less than the plate itself cut into its surface. On the rim thus formed are engraved the sixteen principal points of the compass. The whole face is covered by a glass plate, likewise immovable, which on its inner side has eight diameters intersecting at equal angles, etched in red. These lines are so placed that their extremities mark the sixteen points just mentioned, and consequently they serve as lines of bearing all over the field of the wind disk. Underneath this cover glass, fitting into the recess of the face plate, is a disk of silvered brass, which, by means of a knob passing through the cover glass, can be made to revolve around its center. Four concentric circles divide this disk into five zones corresponding to the zones A, B, C, and D and the central area of a typhoon, as represented on the lower half of Plate I. Above letters will be found in the respective annular sectors. Across the central area is drawn a heavy black arrow, to be set in the direction in which the storm is supposed to move, while in each of the zones the winds prevailing in it are represented by smaller arrows. For the right and left part of the cyclone (with reference to the central arrow) only three wind directions are given in each zone; but for the front and rear five of them are indicated, since it is in these portions that the influence of the progressive movement of the vortex upon the directions of the wind is chiefly felt. The missing arrows can easily be interpolated. As is

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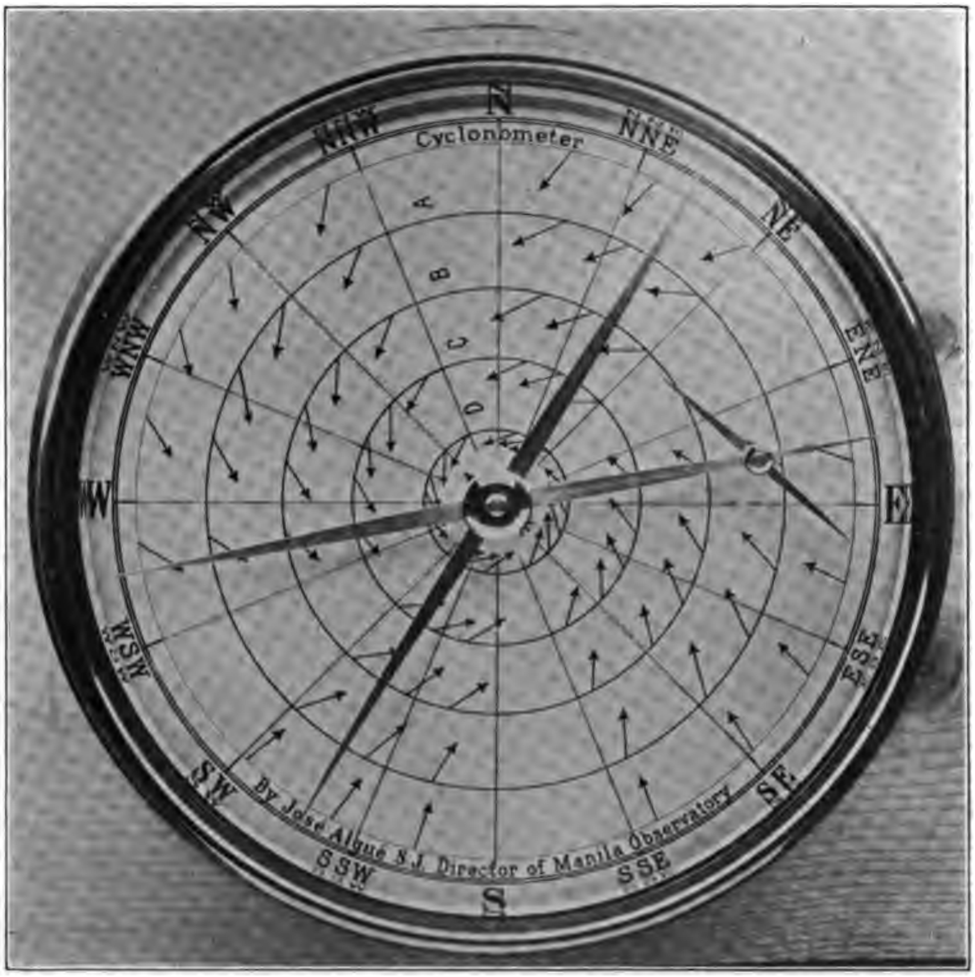
[1] By geodetic position we denote here the position of a place with regard to continents and seas, whether the place is on the coast (and on which coast) or in the interior, on an island, how far from the continent, etc.

Plate XXXIX.



THE WIND-DISK OF THE BAROCYCLONOMETER.

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readily seen, the whole arrangement reproduces a horizontal section of a cyclone near the surface of the earth.

Outside of the cover glass will be seen two needles whose length equals the diameter of the face. These pivot at the center and can be moved directly by hand. One of them bears a graduation, the inner two-thirds of one of its halves being divided into 100 equal parts, with the zero point at the center. In the subsequent description of its use we shall refer to it as the "graduated needle." The other carries, at the point marking the end of the inner two-thirds of its half length, a pivot around which a smaller needle can be turned. We may call it the "double needle."

This may suffice for a description of the barocyclonometer. Its application to the problems, the solution of which it is designed to facilitate, will be shown in the following chapter.

Remarks.—(1) The directions of the wind are inclined toward the center of the cyclone.

(2) The degree of convergence is not the same at various distances, nor is it the same on various sides at the same distance from the center.

(3) The direction of the center exercises an influence upon the variations of the angle between the direction of the wind and the radius vector. The following factors influence the variations in convergence:

(*a*) The direction of the prevailing wind.
(*b*) The topographical conditions.
(*c*) The progressive movement.
(*d*) The shape of zone D.

The general winds which prevail on the edge of the cyclones make their influence felt only at places which are far distant from the center, and in such a way that southerly winds modify the convergence of the winds on the south side, but not of those on the north side. In a similar way northerly winds affect the convergence of cyclonic winds on the north side only, but have no effect on those of the south side. The cyclonic winds of the south side lie between the points northwest through south to southeast, those of the north side between northwest through north to southeast. It results from this for the Archipelago, that, owing to the general winds on the outside of cyclones, the outer cyclonic winds of the southern side—southwest, south, and southeast—show a strong inclination toward the center during the months of the second and third group; during the months of the first group the winds of the northern side are less convergent.

The directions of the wind for zone A of the cyclonometer are more convergent than those of the other zones. It is, of course, impossible to express on the wind disk of the barocyclonometer the influence which the prevailing winds have upon the convergence of cyclonic winds.

The influence which topographical conditions may exercise needs hardly be considered by the sailor. An observer at a fixed observatory will soon find out these influences (as they are exerted, for example, by a mountain chain close at hand).

The wind directions will be less convergent on the front side, owing to the progressive movement of the cyclone, so that they will more approach a circular form than is the case in the rear. The directions of the wind on the two sides of the track undergo, owing to the direction of the track and the intensity of the progressive movement, changes which are all the greater the greater the velocity of the cyclone.

In drawing the wind disk we have taken 45° to be the value of the mean inclination of the wind.[1] The shape of the central region of cyclones changes the wind direction but slightly. As the shape changes a great deal this can not be taken into account when drawing the wind disk. We have preferred to represent it as circular, and this representation can not be a source of serious mistakes.

There is no mention of rain on the dial, because its relation to pressure depends entirely on its causes, and precipitation may occur with different barometric heights, as we have shown in Chapter V of Part I.

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[1] Ferrel, "A Popular Treatise on the Winds," p. 304.

WORKS WHICH MAY BE CONSULTED IN CONNECTION WITH CHAPTER VI.

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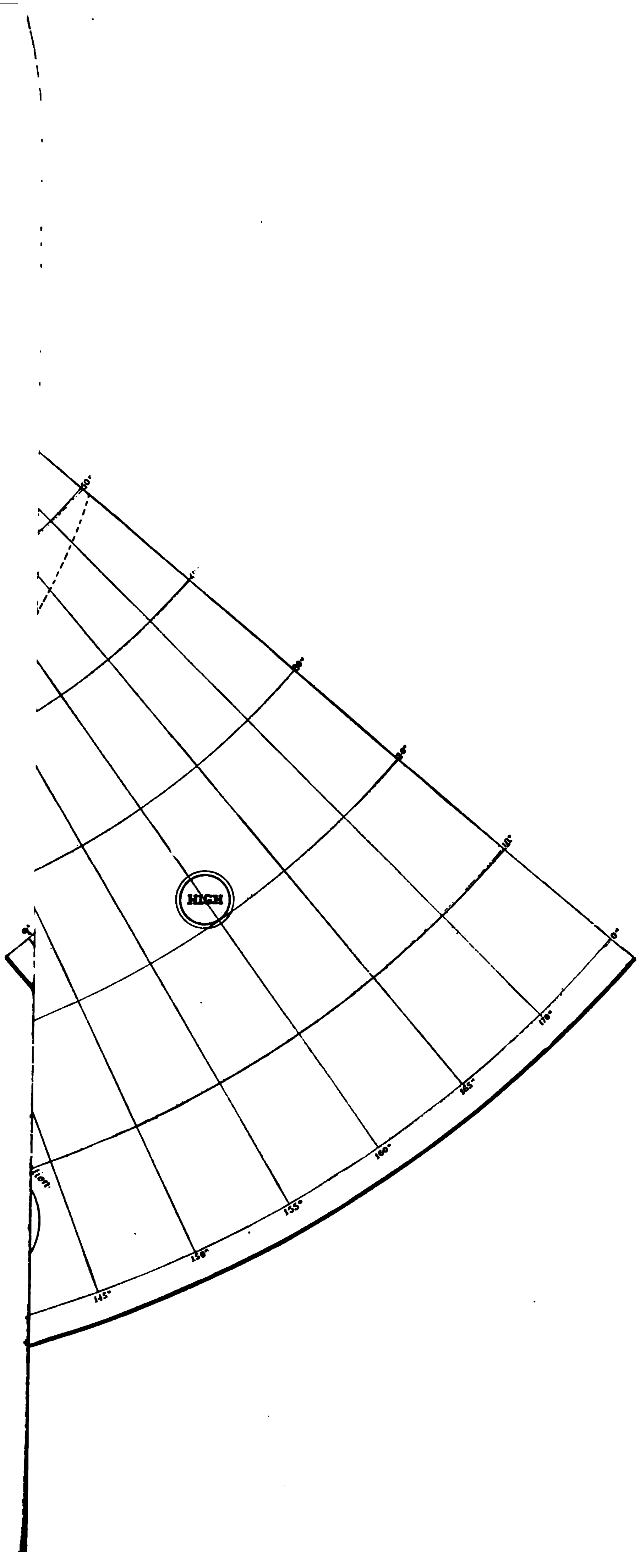

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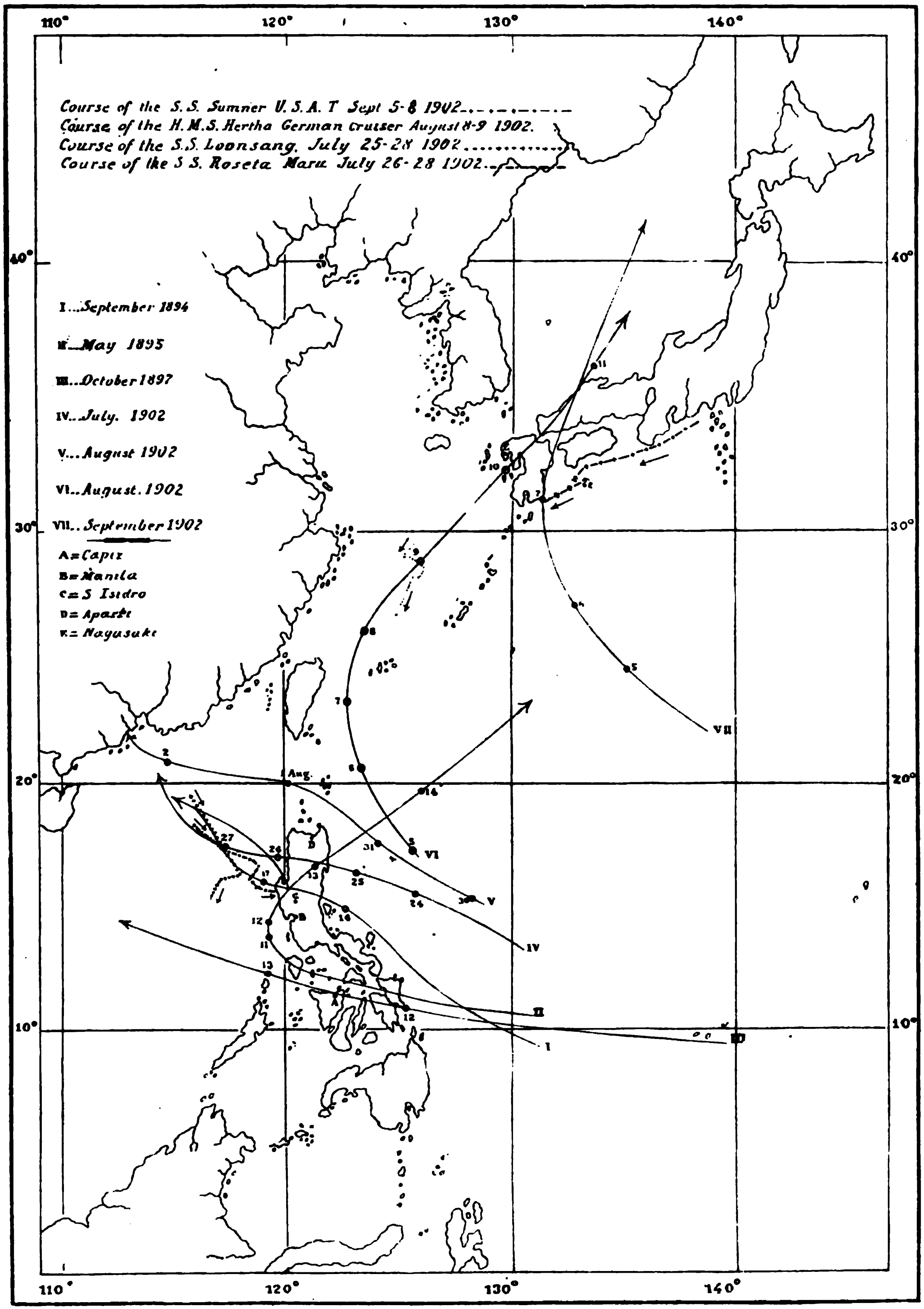
TRACKS OF DIFFERENT TYPHOONS

Plate. XL.

IN CONNECTION WITH THE USE OF THE BAROCYCLONOMETER



Longitude E of Greenwich.

UNIV. OF N. H.

CHAPTER VII. USE OF THE BAROCYCLONOMETER.

If an observer after consulting the given data and rules[1] has satisfied himself of the approach of a cyclone, he must (by turning the projecting knob) set the central arrow of the wind disk in the mean direction of the tracks followed by the cyclones of the region during the respective seasons. For this purpose the mean trajectories followed by the typhoons during the various months of the year have been laid down in the large map accompanying this book. The instrument is now ready for approximately indicating the position and direction of the center.

The first approximation.—The observer must get accustomed to imagining himself placed according to the state of the barometer and the direction of the wind at a point of the concentric rings of the wind disk; this will in no small degree facilitate his calculation. In order to arrive at a first approximation as to the whereabouts of the storm, we must note which of the wind arrows represented in zone A corresponds to the direction of the wind prevailing at the place of observation.[2] If none of the arrows actually drawn corresponds exactly to this wind direction, it will not be difficult to find the place of the ring where the arrow ought to lie. Having found the wind arrow, we must set one of the two large needles in such a way that the plain end of it passes through the starting point of the arrow on the circle; the other end of the needle will then point toward the direction in which the center lies.

If the barometer falls, even though slowly, or if there is a partial change in the barometrical curve but the wind is still blowing from the same point or from a direction close to it, this is a proof that the position of the center has been determined with sufficient accuracy. In proportion as the barometer keeps on falling, the indications given by the wind direction will be more reliable.

The second approximation.—If by a further fall of the barometer and by a partial change in the daily range of pressure the barometrical reading already corresponds to the ring for zone B, we must determine the prevailing direction of the wind and find out the wind arrow in ring B which corresponds to this direction of the wind. Next we must bring the needle to cut the wind arrow at its starting point, as before, then the other end points with greater certainty than before toward the direction in which the center lies. If the wind veers we must repeat the operation. If the wind veers without a total change in the daily curve of the barometer taking place, we may take it for granted that the center will not pass over the place of observation. The instrument shows the observer with sufficient accuracy for practical purposes not only the direction in which the center lies but also—and this is for the sailor most important—the distance of the center and the direction in which it is most probably moving.

The third approximation—The determination of the direction of the center.—If the barometer keeps on falling, the observer determines the prevailing wind direction as before, searches for the corresponding wind arrow and, using now the double needle, brings its single end to cut the wind arrow as before. The end to which the small needle is fastened shows the position of the center. If the wind continues to blow from the same point and the barometer keeps on falling we need not proceed further; the center is approaching the place of observation exactly from the direction which the needle indicates. If, however, the wind direction in two or three hours changes, then we must repeat the observation with the graduated needle, leaving the double needle untouched; we can then by the aid of Fournier's rule find by calculation the direction of the center's advance with sufficient accuracy.

According to Commander Fournier the following proportion expresses the relation between the descent of the barometer within a cyclone and the distance of the center—

$$\frac{P-P_2}{P-P_1}=\frac{D_1}{D_2}.$$

---

[1] See Chapter VI of this part.

[2] With regard to all the applications of the barocyclonometer it is important to remember that, in speaking of wind directions, the direction of the *prevailing* wind is meant, not that of passing gusts and squalls the directions of which are often misleading, especially near the outermost parts of the typhoon.

Here P is the atmospheric pressure at the outskirts of the storm, P_1 and P_2 are the heights of the barometer at two different times of observation, D_1 and D_2 the distances of the vortex at the respective moments. P may be taken from the table given in Chapter V of this part, while P_1 will be the barometer reading at the time of setting the double needle for third approximation, corrected, if necessary, for daily oscillation, and P_2 the reading when the graduated needle is set eventually similarly corrected. $P - P_1$ and $P - P_2$ are consequently easily found. But in order to solve the problem we must know a third term. Not necessarily, because the *absolute* values of the distances do not affect the *direction* in which the center is moving; this direction depends upon their *relative* values and the included angle. But we know—

$$\frac{D_1}{D_2}$$

since the terms of the left side are given. In order to arrive at numerical results we assume D_1 divided into 100 equal parts, thus making it a numerical constant, though the unit by which it is measured may vary within very wide limits. The solution of the proportion will now give us the proportional value of D_2 expressed in a number of the equal parts of D_1, which number may be greater or less than 100.

In the apparatus D_1 is represented by the distance of the pivot of the small needle from the center of the wind disk, which distance, as will be remembered, equals the graduated portion of the other needle=100. Having therefore calculated D_2 from the above proportion, all that is necessary is to set the small needle in such manner that it points to that division line of the graduated needle whose ordinal number is equal to D_2, then the small needle will be parallel to the trajectory of the cyclone.

Corresponding to this direction we turn the disk of the cyclonometer until the central arrow is parallel to the small needle. Should the barometer continue to fall rapidly, it will be very advisable to repeat the whole operation, taking now into consideration the wind directions given for zone C or D. But there is an imperative necessity of repeating the third approximation as often as the *prevailing* wind veers; it may prove disastrous to wait until the wind has run through two or three points of the compass.

It may be well to point out the meaning of the whole procedure. The problem of determining the direction of the trajectory resolves into the following: Given one angle of a triangle and the proportion of the two including sides: find the direction of the third side. The two determinations of the center's bearing, the first of which is laid down on the wind disk by the position of the double needle and the second by that of the graduated needle, give us the included angle, while the fraction—

$$\frac{P - P_2}{P - P_1}$$

furnishes the proportional lengths of the sides. D_1, represented by two-thirds of the half-length of the double needle, having a constant *numerical* value equal to 100 (whatever its linear magnitude may be), we calculate D_2 and lay it off on the graduated needle by pointing the small needle at the corresponding division of the graduated end, which manipulation brings the small needle into a position parallel to the line whose direction is sought—that is, the trajectory of the typhoon.

The determination of the direction of the progressive movement being founded upon mean values, the result is essentially approximate. But there is still another source of inaccuracy. The equation—

$$\frac{P - P_2}{P - P_1} = \frac{D_1}{D_2}$$

states that the decrease of atmospheric pressure from the outer limit of a typhoon to any two points within it is inversely proportional to their distances from the center. There can be no doubt that this assertion is not rigorously true. Still in actual application the error is found to be sufficiently small to give results which have all the accuracy required for practical purposes.

Correction for daily oscillation.—Above we stated that the barometer readings, P_1 and P_2 should be corrected for daily oscillation *if necessary*. For this purpose we give a set of tables containing the mean corrections to be added (algebraically) to these readings, if it is desired to correct them. The tables (pp. 150–154) have been compiled from the records of the observatories of Manila, Hongkong, Zi-ka-wei, Tokio, and Nemuro, and consequently cover the seas most exposed to typhoons. From them the observer can select the one corresponding to his latitude.

Theoretically there can be no doubt that these corrections are required, because the formula—

$$\frac{P - P_2}{P - P_1} = \frac{D_1}{D_2}$$

in which P is a constant mean value, supposes the differences $P—P_1$ and $P—P_2$ to express the barometric fall due to the cyclone. The actual reading, however, gives the combined effect of the cyclone and the daily oscillation, though the latter may be *hidden* by the overwhelming influence of the former.

But practically these corrections will rarely be of great importance. The tables give as *extremes* +1.8 millimeters (0.070 inch) and —1.4 millimeters (—0.056 inch). A glance at the formula makes it clear that whenever the differences $P - P_1$ and $P - P_2$ are rather large, the application or omission of the corrections will have little effect on the resulting value of D_2. Moreover, we must not forget that the whole process is based upon mean values, hence in a concrete case it can not give rigorously exact results. Nor is this necessary. The discrepancy between the values of D_2, as obtained with uncorrected respectively corrected readings, appears chiefly in zones A and B, where the differences $P - P_1$ and $P - P_2$ are small; the nearer we approach the vortex the less the value of D_2 is affected by slight corrections. Now it is easily understood that in the outer parts of the storm a small error in the determination of the direction of the storm's track is not likely to have grave consequences. Still it will be advisable to try the effect of the corrections in zones A and B whenever they have opposite signs for P_1 and P_2, or even when they are of the same quality but the barometric fall between the two observations has been small. We will show by an example the effect which the corrections *can* have in extreme cases.

Suppose, on May 15 at 9 a. m., the barometric reading on board a steamer in the latitude of Manila is found to be 753.2 millimeters (for sea level). The wind having veered, another observation at 4 p. m. gives 747.6 millimeters. Hence the total fall is 5.6 millimeters. But is this due solely to the approach of the cyclone? By no means. During May the correction for oscillation is at Manila —1 millimeter at 9 a. m. and +1.8 at 4 p. m. Fully 2.6 millimeters of the change are therefore due to the daily oscillation.

Applying Fournier's rule to the original readings we have:

$$\frac{755—747.6}{755—753.2} = \frac{7.4}{1.8} = \frac{100}{x} \quad \therefore \quad x = (D_2) = 24$$

But applying the same formula to the corrected readings we obtain:

$$\left.\begin{array}{l} \text{9 a. m.: } 753.2 - 1.0 = 752.2 \\ \text{4 p. m.: } 747.6 + 1.6 = 749.2 \end{array}\right\} \therefore \quad \frac{755 - 749.2}{755 - 752.2} = \frac{5.8}{2.8} = \frac{100}{y} \quad \therefore \quad y = (D_2) = 49$$

If the wind has veered very much between the two observations, this difference in the values of D_2 and the consequent difference in the storm's direction determined therefrom may not be serious, but if the wind has changed only a few points said difference might easily prove disastrous to the steamer.

The statements concerning the effect of the corrections for oscillation are further illustrated and confirmed by the table given at the end of this chapter.

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION.

I. MANILA.

[120° 58′ east of Greenwich; 14° 35′ north latitude.]

Hour	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.008	—0.2	—0.007	—0.2	—0.010	—0.3	—0.012	—0.3	—0.010	—0.3	—0.011	—0.3
2 a. m	0.007	0.2	0.005	0.1	0.004	0.1	0.002	0.1	0.002	0.1	0.001	0.0
3 a. m	0.017	0.4	0.014	0.4	0.011	0.3	0.011	0.3	0.010	0.3	0.009	0.2
4 a. m	0.016	0.4	0.014	0.4	0.013	0.3	0.010	0.3	0.010	0.3	0.011	0.3
5 a. m	0.007	0.2	0.006	0.2	0.005	0.1	0.000	0.0	0.003	0.1	0.006	0.2
6 a. m	—0.006	—0.2	—0.010	—0.3	—0.012	—0.3	—0.014	—0.4	—0.009	—0.2	—0.005	—0.1
7 a. m	—0.024	—0.6	—0.028	—0.7	—0.032	—0.8	—0.032	—0.8	—0.025	—0.6	—0.018	—0.5
8 a. m	—0.042	—1.1	—0.044	—1.1	—0.047	—1.2	—0.049	—1.2	—0.036	—0.9	—0.025	—0.6
9 a. m	—0.053	—1.3	—0.056	—1.4	—0.056	—1.4	—0.055	—1.4	—0.041	—1.0	—0.029	—0.7
10 a. m	—0.047	—1.2	—0.054	—1.4	—0.050	—1.3	—0.047	—1.2	—0.037	—0.9	—0.026	—0.7
11 a. m	—0.031	—0.8	—0.037	—0.9	—0.037	—0.9	—0.033	—0.8	—0.024	—0.6	—0.015	—0.4
Noon	—0.007	—0.2	—0.013	—0.3	—0.013	—0.3	—0.012	—0.3	—0.006	—0.2	—0.002	—0.1
1 p. m	0.024	0.6	0.018	0.5	0.018	0.5	0.021	0.5	0.020	0.5	0.018	0.5
2 p. m	0.048	1.2	0.044	1.1	0.046	1.2	0.048	1.2	0.043	1.1	0.035	0.9
3 p. m	0.061	1.5	0.061	1.5	0.064	1.6	0.065	1.7	0.057	1.4	0.049	1.2
4 p. m	0.056	1.4	0.061	1.5	0.067	1.7	0.070	1.8	0.062	1.6	0.052	1.3
5 p. m	0.041	1.0	0.050	1.3	0.057	1.4	0.063	1.4	0.054	1.4	0.044	1.1
6 p. m	0.026	0.7	0.036	0.9	0.041	1.0	0.042	1.1	0.033	0.8	0.028	0.7
7 p. m	0.008	0.2	0.020	0.5	0.023	0.6	0.022	0.6	0.014	0.4	0.010	0.3
8 p. m	—0.008	—0.2	0.001	0.0	0.003	0.1	0.002	0.1	—0.004	—0.1	—0.008	—0.2
9 p. m	—0.020	—0.5	—0.014	—0.4	—0.016	—0.4	—0.017	—0.4	—0.022	—0.6	—0.024	—0.6
10 p. m	—0.024	—0.6	—0.022	—0.6	—0.027	—0.7	—0.032	—0.8	—0.034	—0.9	—0.035	—0.9
11 p. m	—0.022	—0.6	—0.023	—0.6	—0.030	—0.8	—0.033	—0.8	—0.035	—0.9	—0.038	—1.0
Midnight	—0.017	—0.4	—0.019	—0.5	—0.022	—0.6	—0.022	—0.6	—0.023	—0.6	—0.027	—0.7

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.008	—0.2	—0.010	—0.3	—0.007	—0.2	—0.002	—0.1	—0.003	—0.1	—0.006	—0.2
2 a. m	0.005	0.1	0.005	0.1	0.007	0.2	0.011	0.3	0.012	0.3	0.009	0.2
3 a. m	0.013	0.3	0.014	0.4	0.016	0.4	0.019	0.5	0.022	0.6	0.020	0.5
4 a. m	0.015	0.4	0.016	0.4	0.018	0.5	0.020	0.5	0.022	0.6	0.018	0.5
5 a. m	0.012	0.3	0.012	0.3	0.012	0.3	0.013	0.3	0.013	0.3	0.010	0.3
6 a. m	0.001	0.0	0.004	0.1	0.002	0.1	—0.004	—0.1	—0.004	—0.1	0.003	0.1
7 a. m	—0.011	—0.3	—0.010	—0.3	—0.013	—0.3	—0.020	—0.5	—0.021	—0.5	—0.021	—0.5
8 a. m	—0.020	—0.5	—0.023	—0.6	—0.029	—0.7	—0.034	—0.9	—0.036	—0.9	—0.041	—1.0
9 a. m	—0.026	—0.7	—0.030	—0.8	—0.035	—0.9	—0.043	—1.1	—0.045	—1.1	—0.048	—1.2
10 a. m	—0.024	—0.6	—0.027	—0.7	—0.033	—0.8	—0.040	—1.0	—0.040	—1.0	—0.042	—1.1
11 a. m	—0.017	—0.4	—0.020	—0.5	—0.024	—0.6	—0.024	—0.6	—0.024	—0.6	—0.027	—0.7
Noon	—0.005	—0.1	—0.007	—0.2	—0.004	—0.1	—0.002	—0.1	—0.003	—0.1	—0.005	—0.1
1 p. m	0.014	0.4	0.016	0.4	0.021	0.5	0.023	0.6	0.024	0.6	0.025	0.6
2 p. m	0.029	0.7	0.033	0.8	0.040	1.0	0.044	1.1	0.044	1.1	0.047	1.2
3 p. m	0.040	1.0	0.044	1.1	0.049	1.2	0.053	1.3	0.051	1.3	0.057	1.4
4 p. m	0.044	1.1	0.047	1.2	0.047	1.2	0.048	1.2	0.047	1.2	0.052	1.3
5 p. m	0.038	1.0	0.040	1.0	0.038	1.0	0.036	0.9	0.034	0.9	0.037	0.9
6 p. m	0.024	0.6	0.026	0.7	0.022	0.6	0.023	0.6	0.021	0.5	0.022	0.6
7 p. m	0.007	0.2	0.008	0.2	0.005	0.1	0.004	0.1	0.002	0.1	0.004	0.1
8 p. m	—0.009	—0.2	—0.009	—0.2	—0.012	—0.3	—0.015	—0.4	—0.016	—0.4	—0.014	—0.4
9 p. m	—0.023	—0.6	—0.026	—0.7	—0.028	—0.7	—0.029	—0.7	—0.027	—0.7	—0.025	—0.6
10 p. m	—0.035	—0.9	—0.037	—0.9	—0.037	—0.9	—0.033	—0.8	—0.030	—0.8	—0.028	—0.7
11 p. m	—0.035	—0.9	—0.036	—0.9	—0.033	—0.8	—0.030	—0.8	—0.027	—0.7	—0.024	—0.6
Midnight	—0.024	—0.6	—0.024	—0.6	—0.020	—0.5	—0.020	—0.5	—0.017	—0.4	—0.014	—0.4

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION—Continued.

II. HONGKONG.

[114° 12′ east of Greenwich; 22° 18′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.007	—0.2	—0.010	—0.3	—0.010	—0.3	—0.003	—0.1	—0.003	—0.1	—0.003	—0.1
2 a. m	—0.001	0.0	—0.001	0.0	0.003	0.1	0.012	0.3	0.009	0.2	0.007	0.2
3 a. m	0.007	0.2	0.009	0.2	0.016	0.4	0.023	0.6	0.017	0.4	0.014	0.4
4 a. m	0.011	0.3	0.014	0.4	0.020	0.5	0.025	0.6	0.016	0.4	0.015	0.4
5 a. m	0.008	0.2	0.010	0.3	0.012	0.3	0.015	0.4	0.011	0.3	0.013	0.3
6 a. m	—0.004	—0.1	—0.003	—0.1	—0.004	—0.1	0.000	0.0	—0.002	—0.1	—0.002	—0.1
7 a. m	—0.019	—0.5	—0.020	—0.5	—0.022	—0.6	—0.018	—0.5	—0.019	—0.5	—0.011	—0.3
8 a. m	—0.036	—0.9	—0.035	—0.9	—0.040	—1.0	—0.035	—0.9	—0.032	—0.8	—0.020	—0.5
9 a. m	—0.053	—1.3	—0.048	—1.2	—0.052	—1.3	—0.045	—1.1	—0.041	—1.0	—0.027	—0.7
10 a. m	—0.055	—1.4	—0.054	—1.4	—0.052	—1.3	—0.047	—1.2	—0.041	—1.0	—0.029	—0.7
11 a. m	—0.039	—1.0	—0.043	—1.1	—0.043	—1.1	—0.039	—1.0	—0.036	—0.9	—0.024	—0.6
Noon	—0.012	—0.3	—0.020	—0.5	—0.022	—0.6	—0.025	—0.6	—0.023	—0.6	—0.015	—0.4
1 p. m	0.020	0.5	0.000	0.0	—0.005	—0.1	0.000	0.0	—0.004	—0.1	—0.002	—0.1
2 p. m	0.041	1.0	0.035	0.9	0.031	0.8	0.022	0.6	0.015	0.4	0.013	0.3
3 p. m	0.051	1.3	0.050	1.3	0.048	1.2	0.039	1.0	0.033	0.8	0.025	0.6
4 p. m	0.048	1.2	0.051	1.3	0.054	1.4	0.047	1.2	0.044	1.1	0.036	0.9
5 p. m	0.037	0.9	0.042	1.1	0.051	1.3	0.046	1.2	0.045	1.1	0.036	0.9
6 p. m	0.026	0.7	0.032	0.8	0.040	1.0	0.036	0.9	0.037	0.9	0.029	0.7
7 p. m	0.012	0.3	0.020	0.5	0.026	0.7	0.022	0.6	0.025	0.6	0.014	0.4
8 p. m	—0.003	—0.1	0.005	0.1	0.008	0.2	0.005	0.1	0.007	0.2	—0.002	—0.1
9 p. m	—0.009	—0.2	—0.007	—0.2	—0.009	—0.2	—0.012	—0.3	—0.006	—0.2	—0.013	—0.3
10 p. m	—0.013	—0.3	—0.014	—0.4	—0.019	—0.5	—0.023	—0.6	—0.019	—0.5	—0.025	—0.6
11 p. m	—0.012	—0.3	—0.015	—0.4	—0.019	—0.5	—0.023	—0.6	—0.020	—0.5	—0.024	—0.6
Midnight	—0.011	—0.3	—0.015	—0.4	—0.015	—0.4	—0.016	—0.4	—0.012	—0.3	—0.012	—0.3

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.003	—0.1	—0.005	—0.1	—0.002	—0.1	—0.003	—0.1	—0.003	—0.1	—0.007	—0.2
2 a. m	0.008	0.2	0.007	0.2	0.009	0.2	0.011	0.3	0.007	0.2	0.001	0.0
3 a. m	0.014	0.4	0.015	0.4	0.017	0.4	0.019	0.5	0.016	0.4	0.009	0.2
4 a. m	0.015	0.4	0.018	0.5	0.019	0.5	0.021	0.5	0.020	0.5	0.011	0.3
5 a. m	0.011	0.3	0.015	0.4	0.013	0.3	0.012	0.3	0.017	0.4	0.007	0.2
6 a. m	0.000	0.0	0.005	0.1	—0.001	0.0	—0.004	—0.1	0.001	0.0	—0.005	—0.1
7 a. m	—0.012	—0.3	—0.008	—0.2	—0.015	—0.4	—0.021	—0.5	—0.016	—0.4	—0.022	—0.6
8 a. m	—0.020	—0.5	—0.020	—0.5	—0.030	—0.8	—0.036	—0.9	—0.033	—0.8	—0.040	—1.0
9 a. m	—0.027	—0.7	—0.028	—0.7	—0.038	—1.0	—0.047	—1.2	—0.048	—1.2	—0.054	—1.4
10 a. m	—0.029	—0.7	—0.032	—0.8	—0.041	—1.0	—0.047	—1.2	—0.046	—1.2	—0.054	—1.4
11 a. m	—0.026	—0.7	—0.028	—0.7	—0.033	—0.8	—0.033	—0.8	—0.030	—0.8	—0.038	—1.0
Noon	—0.017	—0.4	—0.017	—0.4	—0.016	—0.4	—0.010	—0.3	—0.006	—0.2	—0.009	—0.2
1 p. m	—0.015	—0.4	—0.001	0.0	0.005	0.1	0.015	0.4	0.024	0.6	0.023	0.6
2 p. m	0.010	0.3	0.016	0.4	0.024	0.6	0.036	0.9	0.041	1.0	0.044	1.1
3 p. m	0.022	0.6	0.030	0.8	0.038	1.0	0.046	1.2	0.048	1.2	0.054	1.4
4 p. m	0.034	0.9	0.039	1.0	0.042	1.1	0.044	1.1	0.044	1.1	0.051	1.3
5 p. m	0.038	1.0	0.041	1.0	0.040	1.0	0.035	0.9	0.034	0.9	0.040	1.0
6 p. m	0.031	0.8	0.034	0.9	0.031	0.8	0.026	0.7	0.022	0.6	0.027	0.7
7 p. m	0.018	0.5	0.018	0.5	0.017	0.4	0.009	0.2	0.005	0.1	0.012	0.3
8 p. m	0.003	0.1	—0.001	0.0	—0.002	—0.1	—0.011	—0.3	—0.011	—0.3	—0.002	—0.1
9 p. m	—0.012	—0.3	—0.019	—0.5	—0.018	—0.5	—0.021	—0.5	—0.018	—0.5	—0.011	—0.3
10 p. m	—0.023	—0.6	—0.029	—0.7	—0.024	—0.6	—0.023	—0.6	—0.023	—0.6	—0.016	—0.4
11 p. m	—0.024	—0.6	—0.027	—0.7	—0.022	—0.6	—0.020	—0.5	—0.021	—0.5	—0.014	—0.4
Midnight	—0.017	—0.4	—0.019	—0.5	—0.015	—0.4	—0.013	—0.3	—0.014	—0.4	—0.011	—0.3

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION—Continued.

III. ZI-KA-WEI.

[121° 26′ east of Greenwich; 31° 11′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.009	—0.2	—0.008	—0.2	—0.012	—0.3	—0.002	—0.1	—0.006	—0.2	—0.006	—0.2
2 a. m	—0.007	—0.2	—0.003	—0.1	—0.004	—0.1	0.007	0.2	0.003	0.1	0.002	0.1
3 a. m	0.000	0.0	0.006	0.2	0.009	0.2	0.017	0.4	0.009	0.2	0.005	0.1
4 a. m	0.007	0.2	0.011	0.3	0.015	0.4	0.020	0.5	0.011	0.3	0.010	0.3
5 a. m	0.007	0.2	0.011	0.3	0.011	0.3	0.016	0.4	0.008	0.2	0.007	0.2
6 a. m	—0.001	0.0	—0.002	0.1	0.003	0.1	0.003	0.1	—0.002	—0.1	—0.002	—0.1
7 a. m	—0.011	—0.3	—0.009	—0.2	—0.012	—0.3	—0.012	—0.3	—0.012	—0.3	—0.012	—0.3
8 a. m	—0.023	—0.6	—0.023	—0.6	—0.026	—0.7	—0.023	—0.6	—0.021	—0.5	—0.020	—0.5
9 a. m	—0.027	—0.7	—0.032	—0.8	—0.033	—0.8	—0.032	—0.8	—0.027	—0.7	—0.022	—0.6
10 a. m	—0.039	—1.0	—0.035	—0.9	—0.034	—0.9	—0.036	—0.9	—0.027	—0.7	—0.022	—0.6
11 a. m	—0.022	—0.6	—0.029	—0.7	—0.028	—0.7	—0.029	—0.7	—0.022	—0.6	—0.019	—0.5
Noon	0.007	0.2	—0.008	—0.2	—0.011	—0.3	—0.017	—0.4	—0.010	—0.3	—0.009	—0.2
1 p. m	0.032	0.8	0.017	0.4	0.010	0.3	0.001	0.0	0.005	0.1	0.004	0.1
2 p. m	0.041	1.0	0.033	0.8	0.028	0.7	0.016	0.4	0.017	0.4	0.013	0.3
3 p. m	0.041	1.0	0.036	0.9	0.036	0.9	0.030	0.8	0.027	0.7	0.021	0.5
4 p. m	0.032	0.8	0.032	0.8	0.038	1.0	0.035	0.9	0.032	0.8	0.029	0.7
5 p. m	0.023	0.6	0.024	0.6	0.033	0.8	0.032	0.8	0.033	0.8	0.032	0.8
6 p. m	0.012	0.3	0.012	0.3	0.023	0.6	0.024	0.6	0.025	0.6	0.026	0.7
7 p. m	0.003	0.1	0.005	0.1	0.014	0.4	0.014	0.4	0.015	0.4	0.013	0.3
8 p. m	—0.006	—0.2	—0.003	—0.1	0.000	0.0	—0.002	—0.1	0.001	0.0	0.000	0.0
9 p. m	—0.012	—0.3	—0.010	—0.3	—0.013	—0.3	—0.015	—0.4	—0.013	—0.3	—0.013	—0.3
10 p. m	—0.013	—0.3	—0.013	—0.3	—0.017	—0.4	—0.019	—0.5	—0.017	—0.4	—0.019	—0.5
11 p. m	—0.011	—0.3	—0.012	—0.3	—0.014	—0.4	—0.017	—0.4	—0.014	—0.4	—0.015	—0.4
Midnight	—0.012	—0.3	—0.009	—0.2	—0.018	—0.5	—0.012	—0.3	—0.015	—0.4	—0.015	—0.4

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.001	0.0	—0.002	—0.1	—0.002	—0.1	0.002	0.1	—0.003	—0.1	—0.006	—0.2
2 a. m	0.007	0.2	0.006	0.2	0.005	0.1	0.008	0.2	0.002	0.1	0.003	0.1
3 a. m	0.012	0.3	0.011	0.3	0.012	0.3	0.015	0.4	0.007	0.2	0.001	0.0
4 a. m	0.013	0.3	0.014	0.4	0.015	0.4	0.018	0.5	0.012	0.3	0.009	0.2
5 a. m	0.009	0.2	0.010	0.3	0.012	0.3	0.012	0.3	0.010	0.3	0.009	0.2
6 a. m	0.001	0.0	0.001	0.0	0.003	0.1	0.003	0.1	0.000	0.0	0.001	0.0
7 a. m	—0.010	—0.3	—0.011	—0.3	—0.009	—0.2	—0.012	—0.3	—0.014	—0.4	—0.010	—0.3
8 a. m	—0.017	—0.4	—0.019	—0.5	—0.019	—0.5	—0.029	—0.7	—0.030	—0.8	—0.023	—0.6
9 a. m	—0.021	—0.5	—0.025	—0.6	—0.027	—0.7	—0.034	—0.9	—0.038	—1.0	—0.036	—0.9
10 a. m	—0.021	—0.5	—0.026	—0.7	—0.028	—0.7	—0.030	—0.8	—0.037	—0.9	—0.038	—1.0
11 a. m	—0.016	—0.4	—0.019	—0.5	—0.020	—0.5	—0.020	—0.5	—0.024	—0.6	—0.023	—0.6
Noon	—0.009	—0.2	—0.008	—0.2	—0.007	—0.2	—0.001	0.0	0.000	0.0	0.004	0.1
1 p. m	0.001	0.0	0.003	0.1	0.008	0.2	0.021	0.5	0.022	0.6	0.028	0.7
2 p. m	0.011	0.3	0.015	0.4	0.020	0.5	0.029	0.7	0.030	0.8	0.038	1.0
3 p. m	0.019	0.5	0.024	0.6	0.025	0.6	0.030	0.8	0.032	0.8	0.038	1.0
4 p. m	0.025	0.6	0.026	0.7	0.023	0.6	0.027	0.7	0.026	0.7	0.030	0.8
5 p. m	0.028	0.7	0.029	0.7	0.019	0.5	0.021	0.5	0.018	0.5	0.021	0.5
6 p. m	0.022	0.6	0.024	0.6	0.013	0.3	0.012	0.3	0.005	0.1	0.009	0.2
7 p. m	0.013	0.3	0.015	0.4	0.004	0.1	0.001	0.0	—0.005	—0.1	—0.001	0.0
8 p. m	—0.001	0.0	0.000	0.0	—0.012	—0.3	—0.010	—0.3	—0.012	—0.3	—0.006	—0.2
9 p. m	—0.013	—0.3	—0.015	—0.4	—0.023	—0.6	—0.017	—0.4	—0.018	—0.5	—0.011	—0.3
10 p. m	—0.019	—0.5	—0.019	—0.5	—0.024	—0.6	—0.018	—0.5	—0.021	—0.5	—0.012	—0.3
11 p. m	—0.017	—0.4	—0.018	—0.5	—0.021	—0.5	—0.014	—0.4	—0.016	—0.4	—0.011	—0.3
Midnight	—0.009	—0.2	—0.009	—0.2	—0.010	—0.3	—0.003	—0.1	—0.007	—0.2	—0.010	—0.3

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION—Continued.

IV. TOKIO.

[139° 45′ east of Greenwich; 35° 41′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.007	—0.2	—0.003	—0.1	—0.010	—0.3	—0.005	—0.1	—0.003	—0.1	0.004	0.1
2 a. m	—0.009	—0.2	—0.002	—0.1	—0.003	—0.1	0.003	0.1	0.002	0.1	0.004	0.1
3 a. m	—0.002	—0.1	0.004	0.1	0.004	0.1	0.005	0.1	0.002	0.1	0.004	0.1
4 a. m	0.002	0.1	0.004	0.1	0.001	0.0	0.004	0.1	0.001	0.0	0.000	0.0
5 a. m	0.000	0.0	—0.003	—0.1	—0.007	—0.2	—0.004	—0.1	—0.009	—0.2	—0.009	—0.2
6 a. m	—0.009	—0.2	—0.011	—0.3	—0.017	—0.4	—0.017	—0.4	—0.019	—0.5	—0.017	—0.4
7 a. m	—0.019	—0.5	—0.026	—0.7	—0.028	—0.7	—0.026	—0.7	—0.025	—0.6	—0.025	—0.6
8 a. m	—0.029	—0.7	—0.034	—0.9	—0.035	—0.9	—0.028	—0.7	—0.028	—0.7	—0.028	—0.7
9 a. m	—0.036	—0.9	—0.035	—0.9	—0.037	—0.9	—0.029	—0.7	—0.025	—0.6	—0.025	—0.6
10 a. m	—0.030	—0.8	—0.030	—0.8	—0.029	—0.7	—0.025	—0.6	—0.022	—0.6	—0.022	—0.6
11 a. m	—0.006	—0.2	—0.016	—0.4	—0.016	—0.4	—0.012	—0.3	—0.013	—0.3	—0.015	—0.4
Noon	0.023	0.6	0.009	0.2	0.002	0.1	0.006	0.2	0.002	0.1	—0.003	—0.1
1 p. m	0.043	1.1	0.033	0.8	0.026	0.7	0.021	0.5	0.015	0.4	0.009	0.2
2 p. m	0.045	1.1	0.043	1.1	0.039	1.0	0.034	0.9	0.027	0.7	0.019	0.5
3 p. m	0.041	1.0	0.042	1.1	0.042	1.1	0.043	1.1	0.034	0.9	0.025	0.6
4 p. m	0.032	0.8	0.038	1.0	0.042	1.1	0.041	1.0	0.036	0.9	0.031	0.8
5 p. m	0.019	0.5	0.025	0.6	0.033	0.8	0.036	0.9	0.035	0.9	0.034	0.9
6 p. m	0.005	0.1	0.012	0.3	0.020	0.5	0.024	0.6	0.027	0.7	0.024	0.6
7 p. m	—0.005	—0.1	0.001	0.0	0.009	0.2	0.009	0.2	0.014	0.4	0.014	0.4
8 p. m	—0.011	—0.3	—0.007	—0.2	—0.004	—0.1	—0.010	—0.3	0.001	0.0	0.002	0.1
9 p. m	—0.014	—0.4	—0.011	—0.3	—0.012	—0.3	—0.017	—0.4	—0.009	—0.2	—0.011	—0.3
10 p. m	—0.014	—0.4	—0.011	—0.3	—0.014	—0.4	—0.018	—0.5	—0.011	—0.3	—0.014	—0.4
11 p. m	—0.012	—0.3	—0.009	—0.2	—0.011	—0.3	—0.017	—0.4	—0.008	—0.2	—0.011	—0.3
Midnight	—0.007	—0.2	—0.007	—0.2	—0.007	—0.2	—0.014	—0.4	—0.002	—0.1	—0.004	—0.1

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.002	—0.1	—0.001	0.0	0.001	0.0	0.002	0.1	0.000	0.0	0.001	0.0
2 a. m	0.003	0.1	0.003	0.1	0.005	0.1	0.006	0.2	0.001	0.0	0.000	0.0
3 a. m	0.003	0.1	0.005	0.1	0.009	0.2	0.009	0.2	0.005	0.1	0.003	0.1
4 a. m	—0.001	0.0	0.003	0.1	0.009	0.2	0.005	0.1	0.002	0.1	0.006	0.2
5 a. m	—0.009	—0.2	—0.006	—0.1	0.003	0.1	—0.002	—0.1	—0.004	—0.1	0.001	0.0
6 a. m	—0.014	—0.4	—0.013	—0.3	—0.005	—0.1	—0.011	—0.3	—0.014	—0.4	—0.012	—0.3
7 a. m	—0.019	—0.5	—0.019	—0.5	—0.014	—0.4	—0.022	—0.6	—0.028	—0.7	—0.022	—0.6
8 a. m	—0.019	—0.5	—0.021	—0.5	—0.018	—0.5	—0.031	—0.8	—0.037	—0.9	—0.033	—0.8
9 a. m	—0.017	—0.4	—0.023	—0.6	—0.022	—0.6	—0.030	—0.8	—0.037	—0.9	—0.042	—1.1
10 a. m	—0.014	—0.4	—0.019	—0.5	—0.020	—0.5	—0.022	—0.6	—0.031	—0.8	—0.036	—0.9
11 a. m	—0.008	—0.2	—0.009	—0.2	—0.009	—0.2	—0.010	—0.3	—0.011	—0.3	—0.019	—0.3
Noon	0.002	0.1	0.003	0.1	0.004	0.1	0.013	0.3	0.015	0.4	0.016	0.4
1 p. m	0.011	0.3	0.014	0.4	0.016	0.4	0.031	0.8	0.032	0.8	0.035	0.9
2 p. m	0.020	0.5	0.024	0.6	0.026	0.7	0.039	1.0	0.037	0.9	0.040	1.0
3 p. m	0.026	0.7	0.031	0.8	0.028	0.7	0.039	1.0	0.035	0.9	0.036	0.9
4 p. m	0.029	0.7	0.031	0.8	0.026	0.7	0.033	0.8	0.031	0.8	0.026	0.7
5 p. m	0.027	0.7	0.028	0.7	0.019	0.5	0.023	0.6	0.021	0.5	0.016	0.4
6 p. m	0.018	0.5	0.020	0.5	0.013	0.3	0.011	0.3	0.010	0.3	0.005	0.1
7 p. m	0.008	0.2	0.007	0.2	—0.002	—0.1	0.001	0.0	0.001	0.0	—0.004	—0.1
8 p. m	—0.003	—0.1	—0.009	—0.2	—0.014	—0.4	—0.006	—0.2	—0.005	—0.1	—0.010	—0.3
9 p. m	—0.013	—0.3	—0.015	—0.4	—0.016	—0.4	—0.011	—0.3	—0.008	—0.2	—0.012	—0.3
10 p. m	—0.015	—0.4	—0.016	—0.4	—0.015	—0.4	—0.010	—0.3	—0.007	—0.2	—0.010	—0.3
11 p. m	—0.014	—0.4	—0.014	—0.4	—0.012	—0.3	—0.006	—0.2	—0.006	—0.2	—0.007	—0.2
Midnight	—0.009	—0.2	—0.008	—0.2	—0.007	—0.2	—0.003	—0.1	—0.003	—0.1	—0.001	0.0

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION—Continued.

V. NEMURO.

[145° 35′ east of Greenwich; 45° 20′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.003	—0.1	0.000	0.0	—0.006	—0.2	—0.001	0.0	—0.008	—0.2	0.004	0.1
2 a. m	—0.005	—0.1	0.002	0.1	0.002	0.1	0.001	0.0	—0.004	—0.1	0.008	0.2
3 a. m	0.001	0.0	0.006	0.2	0.005	0.1	0.003	0.1	—0.001	0.0	0.008	0.2
4 a. m	0.005	0.1	0.005	0.1	0.004	0.1	0.002	0.1	—0.004	—0.1	0.004	0.1
5 a. m	0.003	0.1	0.004	0.1	0.001	0.0	—0.004	—0.1	—0.007	—0.2	—0.001	0.0
6 a. m	—0.001	0.0	0.000	0.0	—0.004	—0.1	—0.011	—0.3	—0.010	—0.3	—0.004	—0.1
7 a. m	—0.011	—0.3	—0.008	—0.2	—0.009	—0.2	—0.013	—0.3	—0.010	—0.3	—0.008	—0.2
8 a. m	—0.017	—0.4	—0.012	—0.3	—0.011	—0.3	—0.011	—0.3	—0.006	—0.2	—0.007	—0.2
9 a. m	—0.019	—0.5	—0.014	—0.4	—0.011	—0.3	—0.014	—0.4	—0.004	—0.1	—0.006	—0.2
10 a. m	—0.014	—0.4	—0.013	—0.3	—0.008	—0.2	—0.006	—0.2	—0.002	—0.1	—0.005	—0.1
11 a. m	0.005	0.1	—0.004	—0.1	0.000	0.0	0.001	0.0	0.005	0.1	0.000	0.0
Noon	0.019	0.5	0.011	0.3	0.011	0.3	0.011	0.3	0.012	0.3	0.006	0.2
1 p. m	0.024	0.6	0.021	0.5	0.022	0.6	0.018	0.5	0.017	0.4	0.010	0.3
2 p. m	0.021	0.5	0.022	0.6	0.024	0.6	0.025	0.6	0.023	0.6	0.012	0.3
3 p. m	0.013	0.3	0.017	0.4	0.020	0.5	0.027	0.7	0.024	0.6	0.013	0.3
4 p. m	0.008	0.2	0.011	0.3	0.015	0.4	0.023	0.6	0.020	0.5	0.013	0.3
5 p. m	0.003	0.1	0.003	0.1	0.008	0.2	0.016	0.4	0.017	0.4	0.009	0.2
6 p. m	—0.004	—0.1	—0.005	—0.1	—0.001	0.0	0.008	0.2	0.008	0.2	0.002	0.1
7 p. m	—0.005	—0.1	—0.009	—0.2	—0.009	—0.2	—0.006	—0.2	—0.001	0.0	—0.005	—0.1
8 p. m	—0.008	—0.2	—0.012	—0.3	—0.014	—0.4	—0.017	—0.4	—0.013	—0.3	—0.014	—0.4
9 p. m	—0.007	—0.2	—0.012	—0.3	—0.016	—0.4	—0.017	—0.4	—0.015	—0.4	—0.016	—0.4
10 p. m	—0.006	—0.2	—0.011	—0.3	—0 017	—0.4	—0.017	—0.4	—0.016	—0.4	—0.015	—0.4
11 p. m	—0.001	0.0	—0.007	—0.2	—0.012	—0.3	—0.014	—0.4	—0.014	—0.4	—0.010	—0.3
Midnight	0.003	0.1	—0.001	0.0	—0.009	—0.2	—0.009	—0.2	—0.008	—0.2	—0.005	—0.1

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	0.004	0.1	0.004	0.1	0.002	0.1	0.000	0.0	—0.003	—0.1	—0.002	—0.1
2 a. m	0.007	0.2	0.008	0.2	0.004	0.1	0.004	0.1	0.000	0.0	—0.004	—0.1
3 a. m	0.008	0.2	0.010	0.3	0.003	0.1	0.003	0.1	0.003	0.1	0.002	0.1
4 a. m	0.002	0.1	0.007	0.2	—0.001	0.0	—0.002	—0.1	0.002	0.1	0.003	0.1
5 a. m	—0.002	—0.1	—0.001	0.0	—0.005	—0.1	—0.004	—0.1	0.002	0.1	0.002	0.1
6 a. m	—0.006	—0.2	—0.004	—0.1	—0.013	—0.3	—0.010	—0.3	—0.004	—0.1	—0.004	—0.1
7 a. m	—0.008	—0.2	—0.007	—0.2	—0.013	—0.3	—0.017	—0.4	—0.014	—0.4	—0.009	—0.2
8 a. m	—0.008	—0.2	—0.008	—0.2	—0.015	—0.4	—0.018	—0.5	—0.017	—0.4	—0.015	—0.4
9 a. m	—0.008	—0.2	—0.009	—0.2	—0.018	—0.5	—0.017	—0.4	—0.016	—0.4	—0.018	—0.5
10 a. m	—0.007	—0.2	—0.006	—0.2	—0.012	—0.3	—0.012	—0.3	—0.011	—0.3	—0.011	—0.3
11 a. m	—0.002	—0.1	—0.002	—0.1	—0.004	—0.1	—0.003	—0.1	0.005	0.1	0.009	0.2
Noon	0.003	0.1	0.003	0.1	0.005	0.1	0.013	0.3	0.023	0.6	0.025	0.6
1 p. m	0.007	0.2	0.009	0.2	0.011	0.3	0.023	0.6	0.025	0.6	0.030	0.8
2 p. m	0.011	0.3	0.015	0.4	0.018	0.5	0.022	0.6	0.023	0.6	0.027	0.7
3 p. m	0.012	0.3	0.015	0.4	0.018	0.5	0.018	0.5	0.015	0.4	0.018	0.5
4 p. m	0.013	0.3	0.012	0.3	0.016	0.4	0.016	0.4	0.009	0.2	0.012	0.3
5 p. m	0.011	0.3	0.011	0.3	0.011	0.3	0.010	0.3	0.002	0.1	0.003	0.1
6 p. m	0.004	0.1	0.005	0.1	0.008	0.2	0.002	0.1	—0.003	—0.1	—0.005	—0.1
7 p. m	—0.002	—0.1	—0.006	—0.2	—0.003	—0.1	—0.001	0.0	—0.006	—0.2	—0.009	—0.2
8 p. m	—0.012	—0.3	—0.013	—0.3	—0.008	—0.2	—0.006	—0.2	—0.009	—0.2	—0.012	—0.3
9 p. m	—0.013	—0.3	—0.013	—0.3	—0.009	—0.2	—0.010	—0.3	—0.010	—0.3	—0.014	—0.4
10 p. m	—0.012	—0.3	—0.013	—0.3	—0.008	—0.2	—0.010	—0.3	—0.008	—0.2	—0.015	—0.4
11 p. m	—0.006	—0.2	—0.009	—0.2	—0.005	—0.1	—0.005	—0.1	—0.004	—0.1	—0.014	—0.3
Midnight	0.000	0.0	—0.004	—0.1	0.000	0.0	—0.004	—0.1	0.001	0.0	—0.008	—0.2

Limitation of the use of the barocyclonometer.—The direction of the cyclone's movement determined by means of the barocyclonometer, as described, has all the reliability which can be secured without telegraphic dispatches from places over which the center is passing in succession, *provided the place of observation has been stationary during the interval between the two observations,* as, for instance, a station on land or a ship at anchor. But what about the chief use of the instrument—that is, on board of ships under way? We are far from claiming for the barocyclonometer a usefulness which it does not possess. We do not recommend its use for determining the direction in which the storm is moving by means of the "third approximation" as long as the ship, steaming on her course, finds herself in zone A. The vessel's speed may be considerable compared with that of the storm's advance, and it might easily happen that, owing to the course of the ship and the distance covered, the small needle pointed in a seemingly entirely wrong direction—as each one may easily ascertain for himself by means of a few pencil lines. But with the vortex at such a distance as the ship's position in zone A implies it suffices to know the direction in which the center lies, the approximate distance of the center and, in a general way, whether the combined effect of its movement and the ship's course and speed brings the observer nearer to the vortex or not. The two latter points can be learned from the indications and behavior of the barometer; the former, with great reliability, from the wind disk. From both together a fairly good estimate can be formed of the direction of the trajectory.

The case is, however, different in zone B, and especially in zone C. There the ship will rarely make much headway while the rapid veering of the wind will allow of making the third approximation at short intervals, so that the place of observation will be but little displaced during the interval, although some allowance should always be made for the ship's course and run.

When applying the barocyclonometer for the purpose for which it has been designed the observer must bear in mind the sound advice concerning the use of this instrument given by Fr. Froc, S. J., in his memoir on the "De Witte Typhoon" of August 1–6, 1901:

> To finish, we will answer a question which has been put to us by several officers, who, at anchor during the typhoon, took advantage of its approach to study the indications of the barocyclonometer, an instrument of somewhat recent use, constructed and perfected by Rev. Father José Algué, Director of the Manila Observatory. This instrument is really very valuable, and may be of most signal service at sea if handled by a practiced observer and read with an experienced eye. One must, however, never forget that like any other apparatus constructed for general requirements, the indications it gives are based upon means, that consequently they may not, in exceptional cases, be taken literally and rigorously, but need, in such circumstances, to be fitted to particular wants. Thus used, the instrument gives useful information, but it would be excessive there to seek a guide for particulars in the study of exceptional cases.
>
> We shall therefore say of it what must be said of all the most perfect instruments of navigation: It is well worth recommending to captains, but neither this nor any other instrument will dispense the commander of a ship to appeal to his experience. This is the most valuable of all instruments, which must never be locked up, particularly when it has been acquired, increased, and enriched by ten, fifteen, twenty years and more of sailing in the same parts, and of conscientious, diligent observation. For a captain thus qualified, certain small signs, insignificant for anyone else, and which it would even be difficult to explain in a general treatise, may give more reliable warnings of the danger than all those that are met with in the best books. Thus the barocyclonometer is a great progress, but it requires commentaries and explanations. We will here only mention one point on which some seamen may have been led astray, namely, the direction of the wind in certain parts on the approach of cyclones, and, to speak of the regions best known to us, we shall limit ourselves to the mouth of the Yangtze-Kiang between the group of the Chusan Islands and the old bed of the Hoangho.
>
> It is almost a rule that, each time a typhoon approaches, particularly when it comes to strike the coast to the south of Ningpo, the bearing of the wind grievously leads in error those who witness the phenomenon for the first time. Keeping to the study of the typhoon of August 3, let us take the report of Zi-ka-wei, printed in the appendix, or that of the North Saddle Island light-house, which is situated farther off. We shall find, at the Observatory, winds (and we may add clouds) coming from the east, and at the light-house continual breezes from east-southeast, force 6, 7, and even 8—that is, typhoon winds—during the whole day, on the 2d, on the 3d, not only when the typhoon landed on the coast, almost right to the south, but at the time when it was clearly in the south-southeast and southeast between Formosa and Nafa.
>
> The explanation which we give without development is twofold. In the first place, the apparent anomaly results from the shape of the isobars, which, far from keeping to the circular or even elliptical shape, assume along the coast undulated, tortuous, and apparently most capricious contours, though all submitted to laws which will some day be formulated.
>
> The second cause of the deviation of the wind, which is not without influence upon the deformation of the isobars, is the call of air taking place generally in summer from the sea toward the overheated plains situated on the continent to the northwest and to the north of Shanghai (Western China, Mongolia, and Chili). The air put in motion by the typhoon ought to incline to northeast or at most to east-northeast. On the other hand, on getting near the coasts it finds a slope and a certain attraction which ought to make it flow from south-southeast or from southeast. As long as the typhoon's vigor has not entered into the period of violence, close to the center,

the air, subject to two forces at an angle between them, follows the resultant and seems to diverge, while at other times of the year—in October, for instance—the air will rush straight in the direction of the center of a distant typhoon.

We would advise those who could find the leisure to study Father Algué's instrument, reading again in quiet, far from the turmoil of the storm, the report of Capt. Geo. Payne, of the steamship *Laisang*, who bore the brunt of the cyclone in open sea. We are confident that this study will be fruitful and lead to satisfactory results.

Practical application of the barocyclonometer.—In order to illustrate the application of the preceding rules we give a few instances taken from actual observations. The calculations are made without corrections for oscillation except in cases in which the difference of the two values of D_2 exceeds five units. In every instance, however, the value *y*, resulting from calculation with corrections applied, is given in brackets.

(1) (*a*) During the typhoon of October 12 and 13, 1897, the famous "Typhoon of Samar and Leyte,"[1] the observations at Capiz, on the Island of Panay, were as follows:

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October 12, 8.05 p.m.: Barometer 738.0 millimeters; wind, SW. }

Capiz is within zone 11°—17°, October in Group II; hence, P = 755. Hence we have, according to formula,

$$\frac{755-738}{755-739}=\frac{100}{x} \quad \therefore x=94 \qquad [y=94]$$

The resulting positions of the needles are given on Plate XLI; and from that follows a direction of the track toward west by north.

(*b*) During the same typhoon the observations at Manila were:

October 13, 6 a. m.: Barometer, 752.38; wind, NE. } Zone A.
October 13, 11 a. m.: Barometer, 753.25; wind, E. }

Hence,

$$\frac{755-753.25}{755-752.38}=\frac{100}{x} \quad \therefore x=149 \qquad [y=145]$$

Plate XLI shows the positions of the needles; the direction of the track is west-northwest by north.

(2) During the typhoon of September 16-17, 1894, the observations at Manila (P = 755) on the 16th were:

September 16, 1 p.m.: Barometer, 749.84; lowest clouds, WNW. } Zone B–C.
September 16, 6 p.m.: Barometer, 746.85; lowest clouds, W. }

According to formula,

$$\frac{755-746.85}{755-749.84}=\frac{100}{x} \quad \therefore x=63 \qquad [y=64]$$

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(3) During the "Gravina Typhoon" of May 13, 1895,[2] at San Isidro, Province of Nueva Ecija, the observations were as follows:

May 13, 10.00 a.m.: Barometer, 749.76; wind, SE. } Zone B.
May 13, 10.30 a.m.: Barometer, 748.00; wind, S. }

The formula reads:

$$\frac{755-748.00}{755-749.76}=\frac{100}{x} \quad \therefore x=75 \qquad [y=80]$$

The direction of the track as shown by Plate XLII was northeast by north.

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[1] See "El Baguio de Samar y Leyte," Manila, 1898.

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[From San Francisco to Manila.]

Date.		Position.				Barometer.	Wind.		Remarks.
Day.	Hour.	Latitude (north).		Longitude (east).			Direction.	Force, 0–12.	
		°	′	°	′	Inches.			
Sept. 5	6.45 a. m	34	18	138	13	29.65	ESE.	2	SSE.; swell; squally.
	10.51 a. m	34	08				ESE.	2	Do.
	2.54 p. m	33	46	136	40	.54			Do.
	8 p. m	33	42			.54	SSE.	5	Mountainous sea from SSE.; squally; exceptionally heavy sea. Expecting we are either overtaking a typhoon coming across the China Sea or are already near its outer edge; put the engine under slow bell and heave the ship to, awaiting results. Very heavy sea running, hard wind and rain squalls of short duration, wind hauling to NE. about 9.30 p. m.
Sept. 6	6.59 a. m	33	02	135	71	.52	NE.	10	Barometer falling $\frac{1}{100}$ of an inch per hour; sea from NE.
	8 p. m	32	30	133	23	.42	NE.	7	Terrible, mountainous sea from NE.
Sept. 7	12.30 a. m	31	57	132	46				Wind and sea increasing; barometer dropping rapidly.
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	4.03 p. m	32	05	133	25	.09	E. by N.	12	
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We find that on September 6 at 8 p. m. the barometer reading was 29.42 inches and the wind was blowing strongly from the northeast. The barometer shows that the ship was then in zone B. At 7 a. m. of the 7th the barometer had fallen to 28.22 inches, corresponding to zone C, and the wind came from north by east. The use of the barocyclonometer would have been as follows:

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Capiz is within zone 11°—17°, October in Group II; hence, P = 755. Hence we have, according to formula,

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The resulting positions of the needles are given on Plate XLI; and from that follows a direction of the track toward west by north.

(*b*) During the same typhoon the observations at Manila were:

$$\left.\begin{array}{l}\text{October 13, 6 a.m.: Barometer, 752.38; wind, NE.}\\ \text{October 13, 11 a.m.: Barometer, 753.25; wind, E.}\end{array}\right\}\text{Zone A.}$$

Hence,

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According to formula,

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The formula reads:

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The direction of the track as shown by Plate XLII was northeast by north.

---

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We find that on September 6 at 8 p. m. the barometer reading was 29.42 inches and the wind was blowing strongly from the northeast. The barometer shows that the ship was then in zone B. At 7 a. m. of the 7th the barometer had fallen to 28.22 inches, corresponding to zone C, and the wind came from north by east. The use of the barocyclonometer would have been as follows:

Before commencing operations the observer would have set the central arrow of the wind disk in the direction of the mean trajectory of typhoons for the ship's place (32° 30′ north latitude and 133° 23′ east longitude) during September. The large chart shows this to be southwest-northeast. Having set the central arrow in this direction, he would have determined the ship's position relative to the vortex at 8 p. m. of the 6th, using the single end of the "double needle." The wind was from the northeast, the barometer reading indicated that he was in zone B. He would have moved the double needle until its single end passed through the tail end of that arrow in zone B, which was most nearly parallel to the direction of the wind—that is, northeast-southwest—then the other, double, end of the needle would have shown that the vortex lay south by east of the ship. After the observation at 7 a. m. of the next morning he would have determined the new position of the vortex by means of the plain end of the "graduated needle," without disturbing the rest of the arrangement. The barometer now showed that the ship was in zone C, the wind came from north by east. There is no arrow in zone C of the wind disk, which (with the arrangement described, see plate) is parallel to the north by east and south by west line. But Plate XLIII, which represents the present case, shows that the position of this arrow is between northwest and north-northwest—

about 4° west of the latter point. By making the plain end of the second needle pass through the interpolated point the observer would have found that he had then the vortex to the south-southeast. For the use of Fournier's rule the two observations furnished the following data:

September 6, 8 p.m.: Barometer, 29.42 inches; wind, NE.
September 7, 7 a.m.: Barometer, 28.22 inches; wind, N. by E.

The ship being between 25° — 32° (at least on the 7th), and September belonging to Group III, the value of P was 29.65 inches.

Hence,

$$\frac{29.65-28.22}{29.65-29.42}=\frac{100}{x} \quad \therefore x=19 \qquad [y=20]$$

With disposition of the apparatus as described, the small needle pointing to 19 on the graduation of the graduated needle would have shown the track of the cyclone to be south by west to north by east. However, the course of the ship during the interval between the two observations, which was south by east, would have had to be taken into consideration. On account of this course the instrument would have shown a less inclination of the track to the northeast than it actually had. The composed direction was north-northeast. (See Pl. XL.)

The vortex was, therefore, recurving to the west of the ship, as was shown in the Weather Bulletin for September, 1902, issued by the Philippine Weather Bureau.

(5) (*a*) At noon July 26, 1902, the barometer on board the steamship *Loonsang* was 29.33 inches, and the wind blew from west by north; she was in zone C. At 3 p. m. the barometer had fallen to 29.22 inches, and the wind had backed to southwest. By Fournier's rule we have:

$$\frac{29.73-29.22}{29.73-29.33}=\frac{100}{x} \quad \therefore x=78.$$

The position of the needles would have been as shown on Plate XLIII, the resulting direction being east by south—west by north.

The calculation with readings corrected for daily oscillation gives a somewhat different result. Since the ship was below the twenty-first degree of north latitude, we take the corrections from the Manila table:

July 26, noon, 29.33 — 0.02 inches = 29.31 inches.
July 26, 3 p.m., 29.22 + 0.02 inches = 29.24 inches.

Hence,

$$\frac{29.73-29.24}{29.73-29.31}=\frac{100}{y} \quad \therefore y=86$$

The direction corresponding to this value of D_2 is shown on the plate by means of a dotted line.

(*b*) On the same day, July 26, at 3 p. m. the barometer of the steamship *Rosetta Maru* stood at 29.22 inches, and the wind came from north-northwest. At 6 p. m. the barometer indicated 29.12 inches, with the wind blowing from northeast.

Fournier's formula gives,

$$\frac{29.73-29.12}{29.73-29.22}=\frac{100}{x} \quad \therefore x=84 \qquad [y=80]$$

The track resulted, therefore, as shown by the small needle on Plate XLIV, east-northeast by north to west-southwest by south. But owing to the ship's course being almost opposite to the motion of the vortex (see Pl. XL), the composition of the two motions will give the true direction of the track, which in the present case will be east by south to west by north, as was the case with the *Loonsang*.

(*c*) On the 27th at 3 a. m. the barometer reading on the *Rosetta Maru* was 28.85 inches with wind coming from southeast. Comparing this observation with the one made at 6 p. m. on the preceding day, we find by Fournier's rule:

$$\frac{29.73-28.85}{29.73-29.12}=\frac{100}{x} \quad \therefore \quad x=69 \qquad [y=70]$$

The small needle will point to northwest, and, composing this with the ship's course, we find that the average direction of the center from 6 p. m. of the 26th till 3 a. m. of 27th was northwest by west. (See Pl. XLIV.)

(6) Another typhoon which was felt so severely in Hongkong in the beginning of August, 1902, crossed to the north of Aparri on the evening of July 31. The trajectory found by means of the barocyclonometer was east by south to west by north. Aparri was successively in zones A and B from July 31 to August 1, and the following observations were made:

$$\left.\begin{array}{l}\text{July 31, 10 p. m.: Barometer, 751.1 millimeters; wind, NW.}\\ \text{August 1, 6 a. m.: Barometer, 746.4 millimeters; wind, WSW.}\end{array}\right\}\text{Zone B.}$$

Whence we have,

$$\frac{755-746.4}{755-751.1}=\frac{100}{x} \quad \therefore \quad x=45.$$

Applying the corrections for daily oscillation we obtain the following:

$$\left.\begin{array}{l}\text{July 31, 10 p. m.: } 751.1-0.9=750.2 \text{ millimeters}\\ \text{August 1, 6 a. m.: } 746.4-0.0=746.4 \text{ millimeters}\end{array}\right\}, \text{ which gives } y=55.$$

The two resulting directions are shown on Plate XLV.

(7) Observations made on board the German cruiser *Hertha* furnish some very interesting instances concerning the use of the barocyclonometer. From observations made at Nagasaki (see No. 8) we learn that that harbor was within zone A of a typhoon (passing afterwards close by to the south) on the morning of August 8, 1902. Hence the *Hertha*, which had left Nagasaki at 3.25 p. m. of the 7th, and was some hundred miles to the southeast by south of the port at noon of the 8th, found herself far within zone A. In fact at 8 p. m. of the 8th the barometer showed 751.79 millimeters—that is, between zones A and B—and at midnight it had fallen to 748.87 millimeters. By that time the ship had entered zone B. By taking the readings and wind directions we can find the bearing of the center of the typhoon at the corresponding hours.

OBSERVATIONS MADE ON BOARD THE GERMAN CRUISER HERTHA.

No.	Date.		Barometer.	Wind.	Zone.	Fournier's formula.		Track of center to—	Approximate distance of center.
	Day.	Hour.				Uncorrected readings.	Corrected readings.		
			Mm.						*Miles.*
1	Aug. 8	Midnight.	748.87	ESE.	B.	------	------	------------	138
2	Aug. 9	2.00 a.m.	745.61	ESE.	C.	------	------	------------	118
3	----do ---	5.30 a.m.	743.01	SE. by E.	C.	74	73	NE.	79
4	----do ---	7.30 a.m.	740.58	E.	C.	80	78	NE. by E.	55
5	----do ---	8.30 a.m.	739.85	ESE.	C.	94	93	NE. by E.	42
6	----do ---	10.00 a.m.	730.99	SE. by E.	D.	60	60	NE. by E.	21
7	----do ---	11.45 am.	712.37	SE.	D.	54	55	NE. by E.	8

Observations 1 and 2 can not be combined for a determination of the direction of the trajectory since the wind had not changed during the interval.

The combination of readings 2 and 3 furnishes a remarkable instance of the influence of the ship's course upon the trajectory as found by means of the instrument. The small needle pointing to 74 gives the direction south by west and north by east, the course of the ship being almost southeast at that time. The actual bearing of the center, therefore, ought to have been, during the interval of the two readings, from about southwest to northeast. The position of the needles is shown on Plate XLV. Another instance is found by combining readings 6 and 7.

8. During the same typhoon which gave such a rough shaking to the *Hertha* another man-of-war, the French cruiser *Friant*, was at anchor in the harbor of Nagasaki. The following table exhibits the observations made on board and the results derived therefrom:

OBSERVATIONS MADE ON BOARD THE FRENCH CRUISER FRIANT.

No.	Date.		Barometer.	Wind.	Zone.	Fournier's formula.		Track of center to—	Approximate distance of center.
	Day.	Hour.				Uncorrected readings.	Corrected readings.		
			Mm.						*Miles.*
1	Aug. 9	8.00 a.m.	752.9	NE.	A.				
2	do	Noon.	751.9	ENE.	A.	52	70	NE. by E.	300
3	do	Midnight.	748.3	E.	B.	37	39	NE. by E.	200
4	Aug. 10	4.00 a.m.	745.4	ESE.	C.	66	72	NE. by E.	120
5	do	8.00 a.m.	740.2	ENE.	C.	62	57	NE. by E.	90
6	do	Noon.	729.3	NNE.	D.	56	57	NE. by E.	50
7	do	2.00 p.m.	728.8	N. by W.	D.	98	100	NE. by E.	25
8	do	4.00 p.m.	736.0	NW.	D.	139	143	NE. by E.	

Fournier's rule has been applied by combining observations 1 and 2, 2 and 3, and so on. The direction of the trajectory thus found coincides with Track VI on Plate XL.

Important caution.—Before applying the barocyclonometer it is of the greatest importance to ascertain whether the aneroid of the apparatus as installed in the chart room or the captain's cabin shows the pressure corresponding to its elevation above sea level or to the sea level itself. It should be corrected to show the latter.

Table of comparison.—To close this chapter we present the comparative table spoken of on page 150. The same needs no further explanation.

Zone.	Place of observation.	D_2 from uncorrected readings.	D_2 from corrected readings.	D_2-D_2.	Correction to P_1.	Correction to P_2.	Fall of barometer during interval, corrected for oscillation.
					Mm.	*Mm.*	
A.	Manila	149	145	+ 4	— 0.1	— 0.6	—[1] 0.82
A.	Nagasaki (Friant)	52	70	—18	— 0.5	— 0.2	0.7
B.	San Isidro	75	80	— 5	— 1.0	— 0.8	1.56
B.	Aparri	45	55	—10	— 0.9	0.0	3.8
B.	Nagasaki (Friant)	37	39	— 2	— 0.2	— 0.2	3.6
B–C.	Manila	63	64	— 1	+ 0.6	+ 0.6	2.99
C.	U. S. A. T. Sumner	19	20	— 1	0.0	— 0.3	[2] 30.70
C.	Steamship Loonsang	78	86	— 8	— 0.5	+ 0.5	[3] 1.8
C.	Cruiser Hertha	74	73	+ 1	+ 0.20	+ 0.15	2.65
C.	do	80	78	+ 2	+ 0.15	— 0.15	2.73
C.	do	94	93	+ 1	— 0.15	— 0.40	0.98
C.	Nagasaki (Friant)	66	72	— 6	— 0.2	+ 0.4	2.3
C.	do	62	57	+ 5	+ 0.4	— 0.5	6.1
D.	Capiz	94	94	0	— 0.7	— 0.9	1.02
D.	Steamship Rosetta Maru	84	80	+ 4	— 1.0	+ 0.5	[4] 3.05
D.	do	69	70	— 1	+ 0.5	+ 1.0	[5] 6.35
D.	Cruiser Hertha	60	60	0	— 0.40	— 0.70	9.16
D.	do	54	55	— 1	— 0.70	— 0.53	18.45
D.	Nagasaki (Friant)	56	57	— 1	— 0.5	— 0.2	10.6
D.	do	98	100	— 2	— 0.2	+ 0.4	—0.1
D.	do	139	143	— 4	+ 0.4	+ 0.7	—7.5

---

[1] Barometer rose.

[2] Fall, 1.21 inches; correction of P_2 = 0.01 inch.

[3] Fall, 0.07 inch; corrections +0.02 inch.

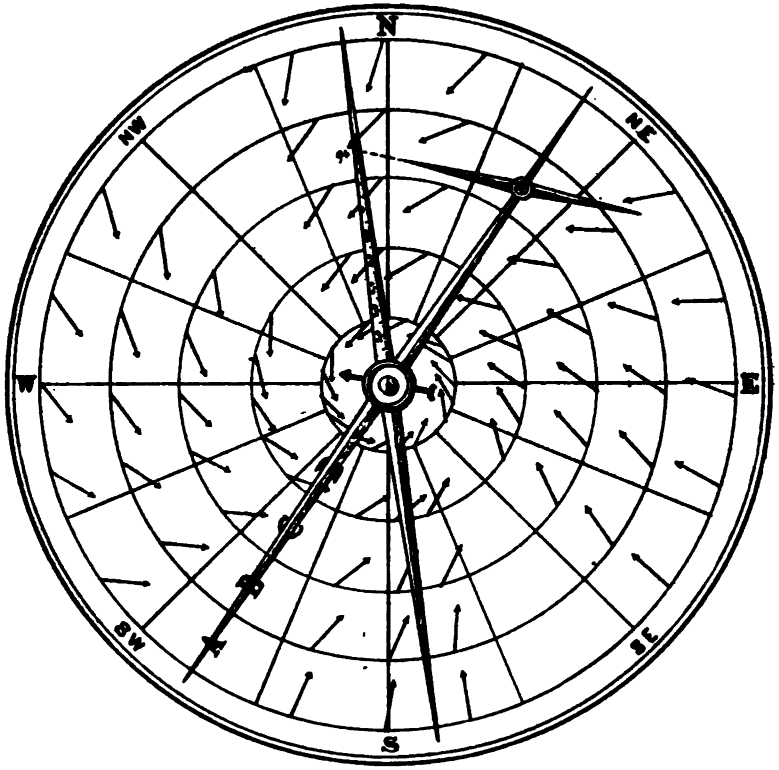
[4] Fall, 0.12 inch; corrections +0.04 and +0.02 inch.

[5] Fall, 0.25 inch; corrections +0.02 and +0.04 inch.

Plate XLI.

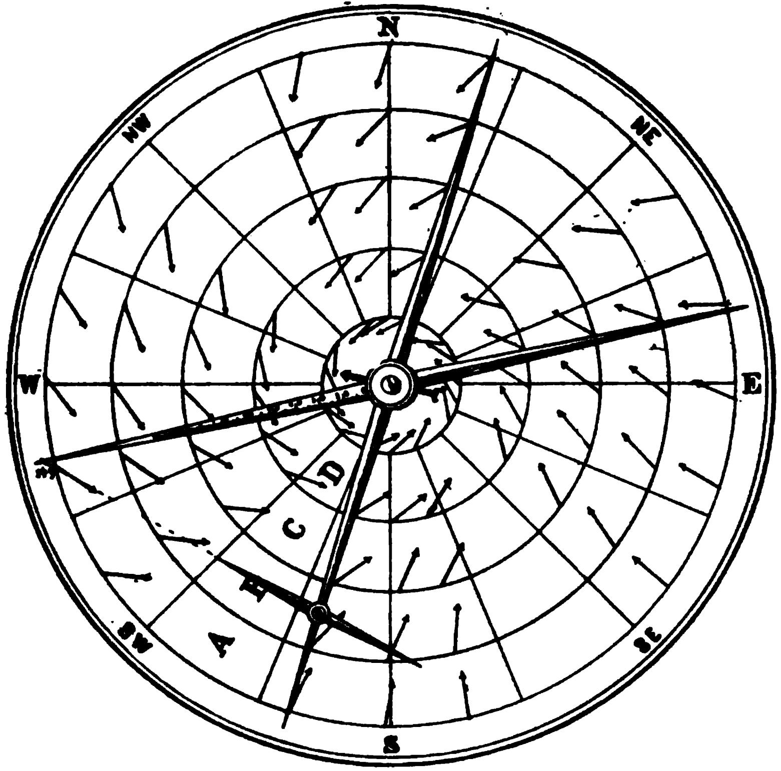
TYPHOON OF „SAMAR Y LEYTE" 1897.

1^{a} Capiz.



Oct 12. and 13.

1^{b} Manila.



October 13.

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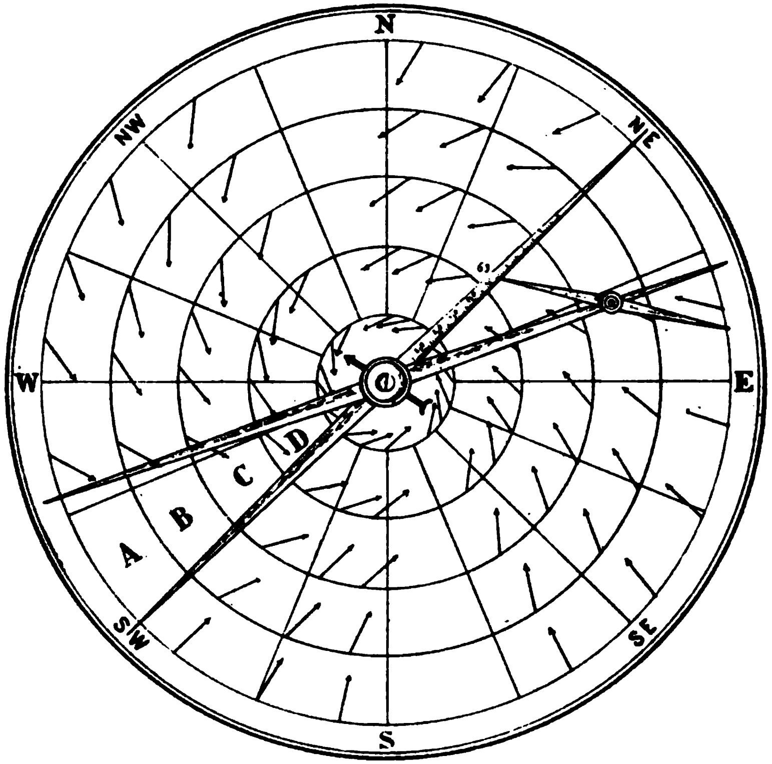
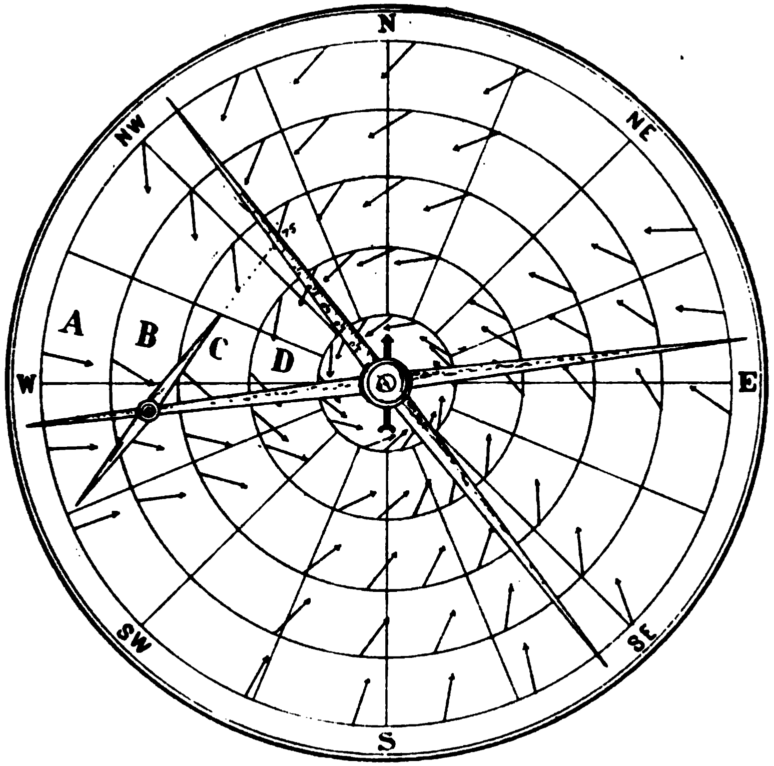
Plate XLII.

2. Manila 1896.



September 16.

3. San Isidro 1895.

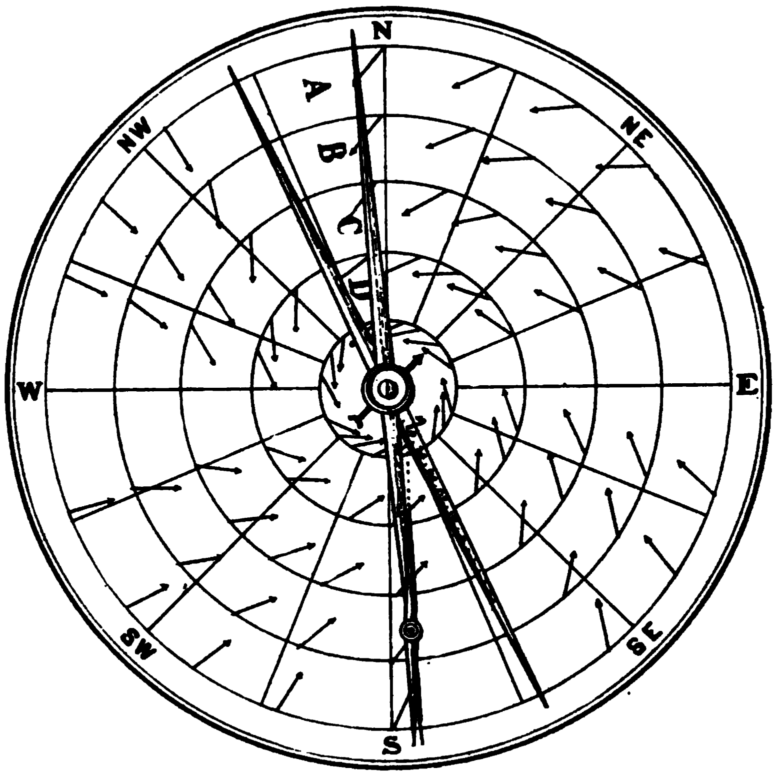


„Gravina" cyclone, May 13.

UNIV. OF

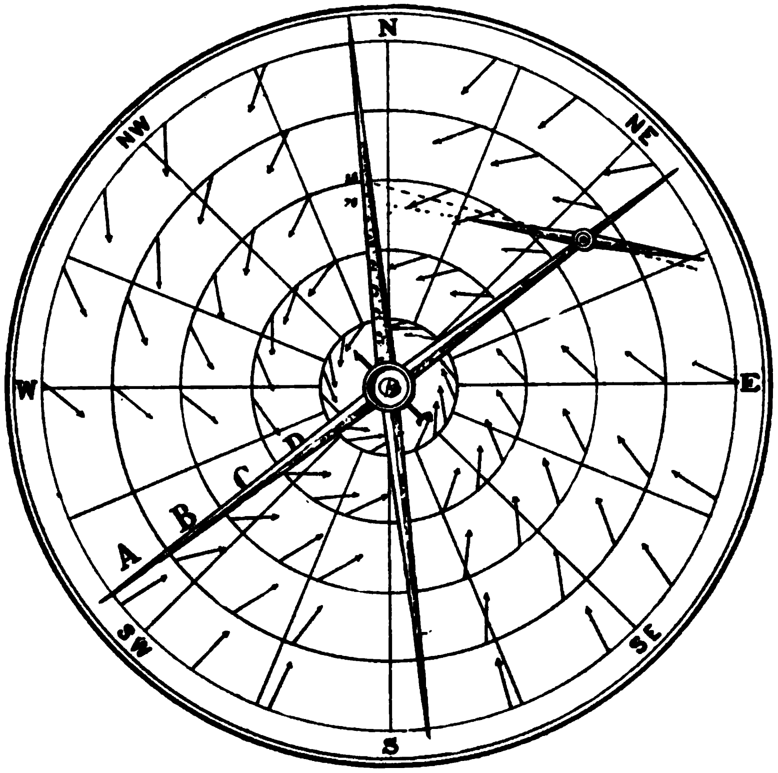
Plate XLIII.

4 U.S.A.T. Sumner 1902.



September 6.-7.

5ª S.S. Loonsang 1902.

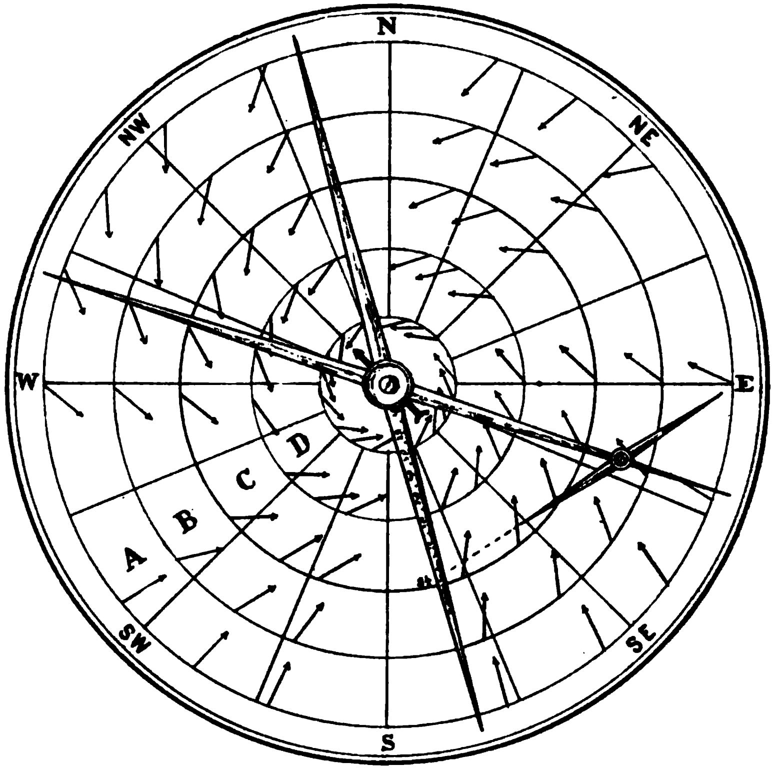


July 26.

Plate XLIV.

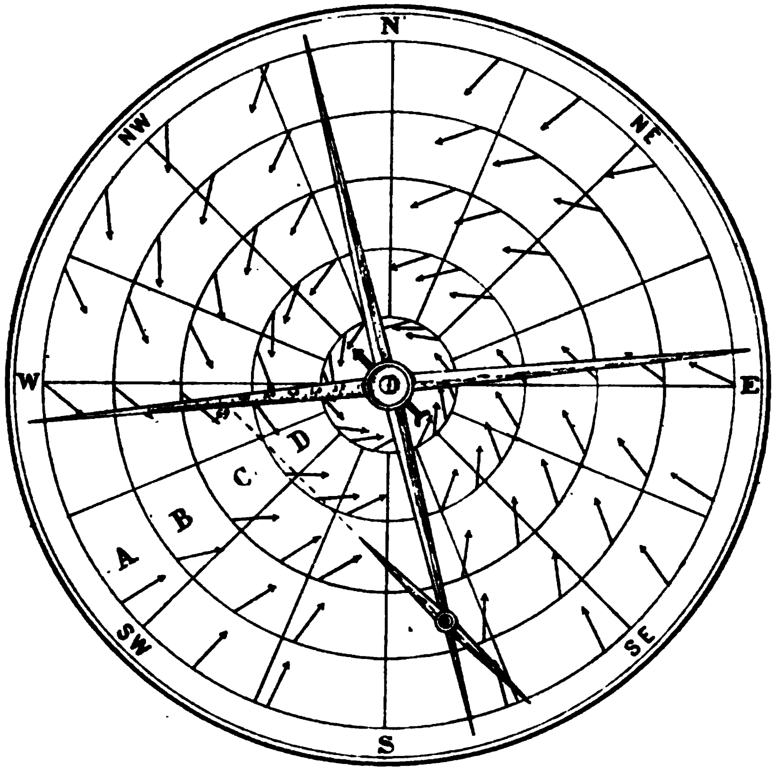
S.S. ROSETA MARU 1902.

5.b



July 26.

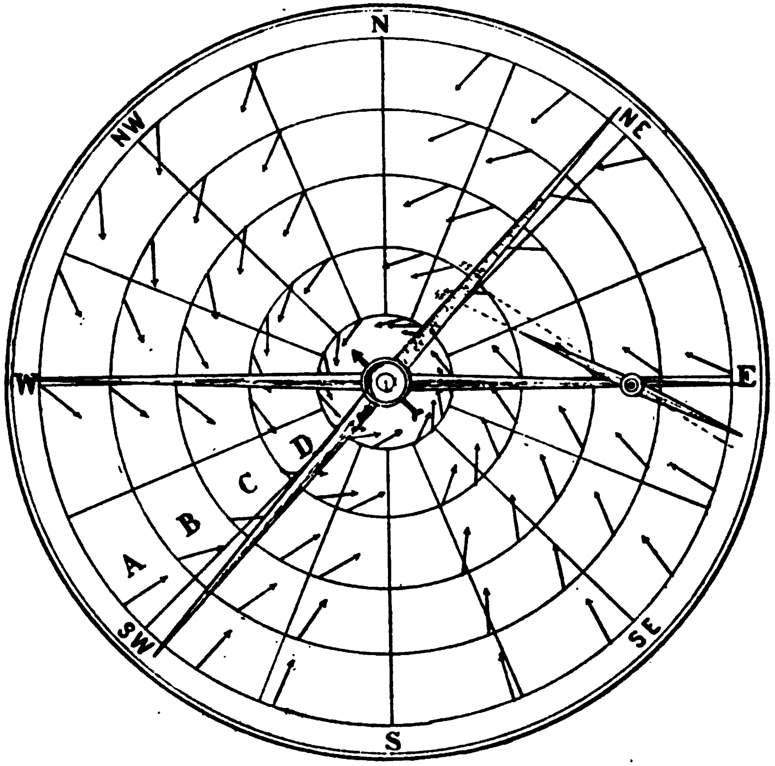
5.c



July 27.

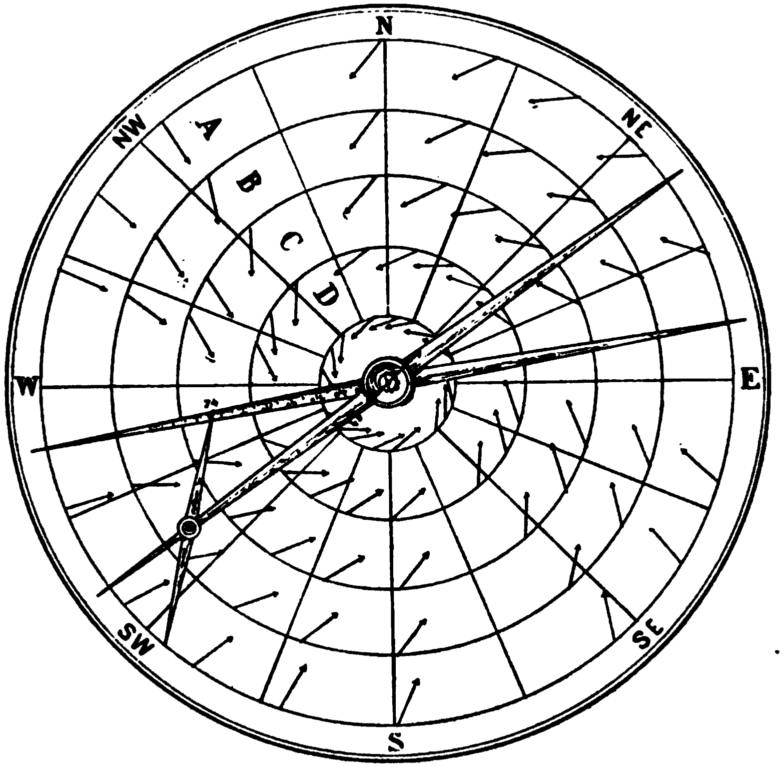
Plate XLV.

6. Aparri 1902.



July 31.–Aug 1.

7. German Cruiser Hertha 1902.



August 9.

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CHAPTER VIII. INDIRECT PRECURSORY SIGNS—THE HURRICANE WAVE AND SWELL.

Thus far we have explained the direct precursory signs of typhoons and shown how a skillful combination of their indications, facilitated by the barocyclonometer, enables the observer to determine his position within the body of the storm and also the probable direction of the latter's translatory movement. The present chapter we shall devote to a discussion of the most important of the indirect signs, viz., the swell of the sea caused by the storm. Its great import for the mariner lies in the fact that it is a truly precursory sign, warning him, whether on the high sea or near the coast, sufficiently in advance of the vicinity of a typhoon.

To avoid confusion we must distinguish between the "storm wave" and the "storm swell." The former is the sea which has been uplifted within the vortex of the cyclone and probably is the effect of the great reduction of atmospheric pressure prevailing there. An experienced seaman, and one who knows the cyclones of our seas well, wrote in 1874:

> Cyclones are accompanied by a great upheaval of the water of the sea called the "cyclone wave," which must owe its origin to the same cause that brings about the great fall of the barometer.[1]

It is clear that this immense heap of water, accumulated within the vortex and following its onward movement, can not be a precursory sign. But the matter is entirely different with regard to the storm swell, which, although it is caused by the hurricane wave, is nevertheless a true precursory sign, *its velocity being much greater than the rate of advance of the typhoon.*

There is no doubt concerning the existence of this swell, as so many authors affirm to have seen it.

> While sailing on the borders of the Tropics in the northern Atlantic, I have frequently watched the gradual change in the direction of the swell, supposed to proceed from distant gales of wind, and it seemed to change in conformity to the usual progressive track of storms. When living in the Bermuda Islands I was frequently interested by observing the change of direction in the surf which beat against their shores. A coming storm would roll its undulations so as to break upon the south and southwest side of these Atlantic islands; and as gales proceeded northward the sea was seen breaking on their northern reefs.
>
> On May 21 and 22, 1843, a strong wind from the northwest and west-northwest was blowing off shore at Madras and at Ennore, while a heavy swell came rolling against the wind from the eastward. The barque *Orpheus* lay at anchor off Ennore. This swell was no doubt caused by a storm which, coming from the southeast at the time, was moving northwest in the direction of Masulipatam.
>
> The master attendant of the dockyard of Trincomalee, in a report of the weather during a hurricane which passed over that place in 1845, says: "There has not been a settled gale of wind at Trincomalee for eleven years, but we have frequently had in the months of November and December a heavy swell rolling in from the northeast, when there have been gales in the Bay of Bengal."[2]

The swell of the cyclone.—What these authors say is often noticed:

(1) On those parts of the coast of China which are not protected by the Island of Formosa, when a cyclone is crossing the Pacific Ocean.

(2) On the southern coasts of China when there is a typhoon in the South China Sea.

(3) On the open east coasts of the Archipelago, hence on the east coasts of Luzon, Samar, Leyte, Dinagat, and Mindanao, when a cyclone develops in the Pacific or crosses it.

---

[1] "Baguios," D. Manuel Villavicencio, 1874, p. 41.

[2] Reid, "Law of Storms," p. 32.

(4) On the south and east coast of Japan when there are cyclones in the Pacific.

(5) On the west coasts of the Archipelago when there is a typhoon in the China Sea, and also when the vortex is lying near the east coasts.

(6) On the coasts of the western and eastern Carolina and Marianas Islands when a cyclone is traversing the Pacific.

(7) Finally, as we may suppose, in the Pacific and the China Sea itself, and accordingly on the open sea.

> **Character and direction of the swell.**—The great depression which originates in the interior of the meteor [says Fr. Viñes], especially toward its central region, causes the hurricane to act by aspiration on the waters and raises and suspends them in quantity proportional to the excess of the external over the internal pressure, in a manner analogous to what takes place in the air pump from the time when a partial vacuum begins to be produced in the body of the pump. The impulse of the revolving, converging winds contributes to this same effect, producing converging currents in the sea which tend to heap up the waters at the vortex of the cyclone.
>
> The waters accumulated under the influence of these two causes form the so-called hurricane wave, a pyramidal and deformed wave, whose crest or vertex corresponds approximately with the vortex of the cyclone. This immense wave always accompanies the meteor in its movement of progression, and on being thrown against the coast it makes the water rise to an extraordinary and sometimes astonishing height, causing terrible inundations and spreading everywhere terror and desolation.[1]

Theoretically speaking, there are two agencies at work in effecting a great change in the level of the ocean when a cyclone moves over it; one is the aspiration of water into the center of the cyclone, which is caused by the extraordinary disturbance of the equilibrium of the atmosphere. The effect of this force is a centripetal motion of the water of the sea, the violence of which depends on the greater or less disturbance of the atmospheric equilibrium and on the development of the system of the cyclone. The second force is the driving power of that immense cyclone wave piled up in the center, which is produced by the progressive movement of the cyclone. On account of the first of these causes the water, with radial or almost radial centripetal motion, rushes toward the vortex; that is, the swell is directed to the vortex. Owing to the second cause the swell, at least in the anterior part of the hurricane, is driven away from the vortex.

It follows that in the front part of the cyclone the two forces are opposed to each other, but it is not difficult to understand that the driving force, which acts in the direction of the advance, must preponderate if we consider that, in addition to this driving force, gravity also must make itself felt. This gives the water a centrifugal motion and counteracts the aspiration toward the center.

The immense mass of water piled up within the vortex does not move along with the center, though the hurricane wave is permanent. In proportion to the advance of the storm new masses of water being sucked up continually replace those which previously constituted the wave. The latter, thus released from the influence of the force that elevated them, sink back under the action of gravity, thereby causing a huge swell, which tends to propagate itself in all directions. This swell counteracts the centripetal force resulting from the suction of the vortex and actually prevails against it at the front of the cyclone. Whether this is also the case in the rear we are unable to decide owing to lack of data. There certainly have been observed some cases in which the swell in the rear of the storm was directed toward the center. But this may have been due either to some obstacle in the way of the swell or to the fact that in the rear the swell does not overcome the centripetal force. At any rate, for our present purpose it suffices to consider the direction of the swell in front of the storm, since this alone properly constitutes a precursory sign.

The other force, the convergent cyclonic winds, which Fr. Viñes considers to be a contributing cause in the formation of the cyclone wave, we take to be rather a disturbing element. The reason is that though the wind may be somewhat convergent toward the center the convergence is not complete, especially when the wind is violent. Hence the force of the wind which influences the water is not radial, and must therefore counteract the centripetal force in the rear as well as the centrifugal force in the front. In conjunction with these forces it brings about changes of intensity and direction.

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[1] Viñes, "Apuntes Relativos á los Huracanes de las Antillas." Habana, 1877, p. 192.

How far experience confirms these theoretical considerations will be seen later on. As far as the swell of the cyclone is concerned, many facts confirm the statements:

(1) That the swell in the front originates near the center.

(2) That this swell is propagated to very great distances, its strength varying in proportion to the distance. We would state that in the case of its meeting any great obstacle resultant directions are observed which, although explicable, are not always easy to foresee or interpret.

Concerning the storm or hurricane wave, experience teaches that it is the cause of the greatest destruction on the coasts and on the high seas.

In front of the typhoon the swell comes approximately from the direction of the center. The steamship *Don Juan* left Hongkong for Amoy on September 21, 1891, at 10 p. m., encountering a heavy long swell from an easterly direction. It was the very hour at which a cyclone vortex was some distance off to the eastward.[1]

Such cases are often observed in the part of the China Sea which lies in front of the Bashi and Balingtan Channels when a storm field moves through these channels toward the continent. Reid mentions several such instances,[2] some of which we reproduce here for the benefit of those captains who sail only from Manila to Hongkong, or from Hongkong to Amoy and Shanghai.

On September 21, 1803, a typhoon traversed the most extreme part of Luzon; some of the ships of the East India Company which were at that time not far from Macao experienced the effects of the cyclone which, crossing the peninsula of Cape Engaño, entered the continent through the Gulf of Tonkin after traversing the Straits of Hainan.

Abridged log of H. C. ship *Alfred:*[3]

> At noon, 22d September, had the Grand Ladrone bearing W. ½ S., Gap Rock S., and Asses' Ears due E. Observed that the swell was rising from the eastward. Wind marked N. At noon, working into the anchorage. P. M. increasing breeze and cloudy weather, with a long swell from the east. At 4 p. m. anchored with Grand Ladrone bearing S., Gap Rock S. by E., Asses' Ears S. 65° E.; making all snug. At 11 p. m. wind increased to a hard gale NNE.; at midnight, drove.
>
> September 23: Gale still freshening, and ship driving at the rate of 2½ knots per hour; cut and stood to sea; hove to; at 2 a. m. wind at NE., and at 4 at ENE.; heavy gale with hard squalls and a confused sea at noon; at 2 p. m. ESE.; at 4 made some sail; at 7 p. m. ESE.

We learn from these observations that twenty-four hours before the outbreak of the cyclone, while the sky was still clear, the swell was noticed which, on account of its originating near the center, showed also the direction in which it lay.

The bark *Lady Hayes* experienced a typhoon which crossed the China Sea during the first ten days of August, 1835; she was but a few miles distant from Macao. When we examined the observations for the year 1834–1848, which hitherto have not been published, we found that this cyclone was observed at Manila with fresh winds at 2 p. m., and that strong rain and wind squalls from west-northwest and west-southwest occurred at 3 a. m. The barometer reached its lowest point at 3 p. m. The center passed through the Bashi Channel and probably crossed the meridian of Manila at 3 a. m. in the direction west by north. Reid prints a report about this cyclone:

> **Lady Hayes.**[4]—Early on the morning of August 5 we observed indications of bad weather. At 10 a. m. the wind freshened a little from the same quarter it had been in for the last twenty-four hours, viz, north; so we thought it best to turn her head back again to look for shelter, fancying ourselves to be about thirty miles off the land. We carried a press of sail until noon, when we found we had too great a distance to run before we could get into shelter, and expecting it would get so thick that we could not see our way; so we turned her head to sea and clapped on as much sail as she could stagger under, steering southeast by east. The wind being then at north we were desirous of getting as far off the land as possible, expecting the wind round to the eastward,

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[1] See "Boletin Mensual del Mes de Septiembre, 1891, Apendice," and "Apendice al Año 1891: Trayectorias de los Tifones de Septiembre, 1891."

[2] "Progress of the Development of the Law of Storms and of Variable Winds, with the Practical Application of the Subject to Navigation," by Lieut. Col. William Reid, C. B., F. R. S. London, 1849, p. 176.

[3] Loc. cit., p. 177.

[4] Loc. cit., p. 193.

there being a most tremendous swell from that quarter. At 4 p. m. it was blowing in severe gusts and we shipping a good deal of water, and the ship becoming unmanageable. About 8.30 the wind began to veer to the west, but continued to blow as hard as ever till midnight, when it drew round to south and moderated a little. It continued to blow hard from that quarter until noon of the 6th, when it moderated fast, and we began bending other sails in room of those that were split.

The situation relative to the typhoon in which the *Lady Hayes* found herself did not materially differ from that of the *Alfred* or the steamship *Don Juan;* only in her case the vortex moved in slightly higher latitudes. In each of these instances there was a typhoon in the Pacific Ocean which made itself felt on the open coast of China—that is, those opposite the Bashi and Balingtan Channels—where high and long seas came in from the east at least twenty-four hours before the approach of danger.

The ship *Panama*[1] was on the 23d of October, 1831, in 8° 17′ north latitude, and 117° 16′ longtitude east of Greenwich. Wind came out at southward and continued until 10 p. m., then died away, and commenced from the northward with a heavy head sea. Forenoon, breeze from northwest and clear weather. Latitude 9° 45′ north, longitude 117° 25′ east.

October 24: Pleasant breezes from northwest and hazy, steady weather. A sea rolling from the northward. I suppose there has been a gale in the China Sea which has not yet reached us. Evening, wind rapidly increasing, and barometer falling from 29.76 to 29.41 inches. Midnight, reefed topsails, 9 a. m. double reefed topsails, barometer 29.21. Ends with tremendous gale from the westward and heavy sea. Barometer 29.10; latitude 11° 15′; longitude 118° 20′ east.

October 25: Heavy gale west-southwest, barometer 29.02, gale hauling to the southward; evening, more moderate. Made a little sail; wind at 7 p. m. from southwest; 11 p. m. from southward. In the morning at 5 o'clock the wind came out at southeast (barometer 28.70) and blew a perfect hurricane. Hove to under mizzen staysail, barometer at 1 p. m. 29.05, 4 p. m. 29, 7 a. m. 29.10, 8 a. m. 29.20.

The cyclone into which the *Panama* came was most likely moving parallel to the equator, and with moderate velocity, through the southern part of Luzon. The ship was steering on a northeast course on the 23d, and therefore fairly parallel to the coast. On this day the center was presumably approaching the vessel from the northeast. Already on the 24th the high swell was coming from the north, a sign that the cyclone was approaching. As the ship kept on her course the center passed ahead of her, and the vessel was nearest to it on the afternoon of the 25th, when it lay to the north-northwest. The swell was noticed about two days before the arrival of the center.

At the same time when the ship *Lady Hayes* was met by the easterly swell of the cyclone near Macao other vessels were 400 miles further to the south, on the same meridian, in the China Sea; they had a heavy swell from northeast, and afterwards from north-northeast. In view of these facts Reid (loc. cit., p. 195) comes to the following conclusion:

> A storm like this might be expected to draw with it a mass of water from the Pacific, owing to diminished atmospheric pressure, which alone would be sufficient to create a current round the north and west sides of the China Sea, and through the Gulf of Tonkin.

The swell coming from the center of the typhoon is likewise noticed in the higher latitudes of the China Sea. We reproduce a few instances from the pamphlet of Fr. Froc, "The Iltis Typhoon," July 22–25, 1896:

The Chinese steamship *Hsingfung*, Captain Warwick, being at 10 a. m. July 22, in 122° 36′ E. and 35° N., remarks that the wind was freshening between northeast and east; she heads into a light southeast swell: at this moment she was 510 miles off the center.

The Chinese steamship *Haeshin*, Captain McKinnon, was at noon, 21st, off Town Island, in the vicinity of the coast of China to the north of the Formosa Channel (26° 42′ north latitude); she experienced strong northeast breezes and was tossed about by a high east-southeast swell; now she was at more than 500 miles from the center, which was located almost exactly to the east-southeast. This heavy swell, backing little by little to the east, continuously followed the ship up to Gutzlaff which she reached on the 22d, 8 p. m., having successively experienced fresh north-northeast, north, and north-northwest winds.

The I. C. M. customs cruiser *Pingching*, Captain Anderson, during her trip to the light-houses at the mouth of the Yangtze River arrived at Loka, near the east point of Chusan Island. On the 21st, at 4.30 a. m., the captain reports a big and long easterly swell (the wind being at the time from north, force 3) and too much sea to land; so he was compelled to proceed on his voyage in order to make at first the visit to Pei-yu-shan light-house. When the swell was encountered, the center of the typhoon had just passed the Liukiu group and was traveling at a distance of 350 miles.

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[1] Reid, "Progress of the Law of Storms," p. 192.

[2] "Iltis Typhoon," p. 12.

We note, by the way, that the cyclonic waves emerging from the center of this typhoon were observed by the steamship *Diamante* in front and by the steamship *Loodiana* in the rear of the typhoon. The former, bound from Hongkong to Manila, found a heavy swell from the southeast long before the alarming fall of pressure began; and the latter, approaching the end of her voyage from Singapore to Manila, at 6 p. m. on the 19th, being on the parallel 13° 35′ N. and meridian 118° 38′ E., experienced a considerable swell from the northwest, where the typhoon center was, as per the above data.

The swell makes itself felt at a great distance.—The best point about this indication is the great distance at which it may be noticed; and it therefore often makes itself felt before any other indication.

The French steamship *Yarra*, Captain Le Coispellier, L. de V., coming up from Hongkong arrived on the 20th, 4 p. m., to the east-southeast of Namquam Harbor in 26° 56′ N. and 121° 5′ E.; up to this she experienced fresh northeast to north-northeast breezes and a superficial swell coming with the wind. Suddenly the swell rises from the east without any change in the force and direction of the wind. Attributing to the typhoon during the 20th a progressive motion of 10 miles an hour toward the northwest, which does not seem to be exaggerated, since we shall further see it make 12 miles on the 21st, we may then state that at this moment the typhoon's influence made itself felt in a westerly direction at a distance of about 650 miles; at all events, 600 miles will in all probability be less than the truth.[1]

We see, therefore, that a sailor in low latitudes may receive warning from the swell three days beforehand, when the cyclone is still moving with moderate velocity—as, for instance, in the zone of the Archipelago—especially when its direction is different from the direction of the wind blowing at the time.

The French cruiser *Isly* left the Japanese island Kiushiu on the 7th of October, 1896, for Manila, her course at first being southwest by west. In the afternoon of the same day, when she was not far from the latitude of Shanghai and 129° east of Greenwich, a persistent convergence of cirrus was noticed toward the south-southeast; they were the first indications of a cyclone in the Pacific Ocean, which was at that time in 15° north latitude and 133° east of Greenwich, and was therefore about 900 miles distant from the ship. The second indication of the cyclone followed very soon. At noon on the 8th a swell coming from the south-southeast was noticed. The ship's place was, at noon on this date, 29° N. and 126° E. The center of the cyclone was then in 16° N. and 135° E., and, therefore, to the south-southeast and about 800 miles distant from the ship. While the cyclone was recurving in the west of the Channels of Balingtan and Bashi the swell caused by its vortex was felt at Guam (Marianas Islands) on the 10th and 11th, at a distance of more than 1,200 miles, and five days before the passage of the cyclone itself could be noticed there. This is an excellent example, showing that a careful captain is very well able to avoid meeting with a typhoon in the Pacific Ocean. On the 10th the cruiser *Isly* had reached the latitude of about 21° N. and 125° E.; the center was in about the same longitude and in 18° N., that is, 180 miles distant. The reading of the barometer was 751 millimeters (29.57 inches). The ship at 11.30 a. m. was between two swells which were running against each other in opposite directions. The observations do not indicate the directions of these swells, but as the swell which was caused by the violent wind at 9 a. m. veered round at midnight with the wind from northeast to east, we may suppose that one of these swells was created by the typhoon-like wind, while the other probably originated in the center of the cyclone.

On Wednesday,[2] September 8, 1897, toward 12.30 p. m., the magnificent steamship *Empress of India*, Capt. O. P. Marshall, left Kobe bound for Yokohama. The weather was overcast but the atmosphere calm, yet the northeasterly wind, which was anything but a gentle breeze in the forenoon, kept on freshening; shortly after the weather became gloomy, the density of the cloud canopy deepened, its level was reduced and the rain set in. but the barometer did not as yet foretell anything of a portentous character, the maximum of the 8th was even 0.04 inch higher than that of the preceding day. The steamer then entered the Kii Channel and plowed its waves with her usual easy run. Meanwhile the terrible adversary was advancing from the south, on a course which converged with that of the *Empress of India*. The typhoon was at no great distance, and its presence was soon to be detected. The barometer in the Kii Channel was on the decline, and the wind had set to E. ¼ S.; from 6 p. m. no doubt was left; the pressure, which as a rule should have had an upward inclination at this time of the day, gave way by nearly 0.06 inch per hour; in fact, a typhoon to the southwest was rapidly approaching the south coast of Japan.

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[1] Froc, S. J., "Iltis Typhoon," p. 12.

[2] Froc, "The Typhoons of September 9 and 29, 1897," pp. 1, 2.

In addition to the above forerunners of the storm, a most characteristic sign presented itself at 7.45 p. m. The vessel had just rounded the Island of Oö Sima, standing for the offing outside the shelter offered her by the coast, to steer for Uraga Channel, when she encountered a high southwest sea, while the wind from east-southeast increased rapidly in velocity. The cause of this swell can not be ascribed to the deviation caused by the coastal line of the general movement of the sea governed by the action of the east to east-southeast breezes; it was, indeed, a well-defined system of undulations of great volume radiating from the center of the typhoon in all directions and spreading far and wide as heralds of its existence. This example is too striking to be slighted, and I embrace this opportunity of calling, in passing at least, the renewed attention of navigators thereto. Indeed, Captain Marshall upon directing his eyes to the southwest perceived sweeping toward his vessel huge waves combing over in the form of "rollers," which are in their essential parts comparable to the surge that runs from the deep sea on to the sandy coast, and the spray of their foaming crests was caught by the already strong east-southeast winds. Their majestic march revealed the approach of the enemy and indicated the quarter from which it was to spring.

We quote from the Meteorological Review for September, 1900:

> It is worth noting that the swell from the east observed at Middle Dog (China) during the 14th was also observed on the preceding day from 3 a. m., viz, many hours before the center crossed south of Naha and therefore while it was some 500 or 600 miles off the continent. Also the captain of the steamship *Sherman* remarks in his report that after having passed the Colnett Strait (near the parallel 30° N. and the meridian 130° E.) on the morning of the 12th—that is, when the vortex was probably 300 miles distant, good weather prevailing and before the fall of the barometer—she experienced a strong swell from the southeast which veered to the south. Remarkable instances of the wide action of the cyclonic waves![1]

Another very remarkable instance which tends to confirm this point is offered by the Galveston hurricane wave. In a special report of this destructive hurricane of September 8, 1900, Dr. I. M. Cline, official in charge of the Weather Bureau station at Galveston, says[2]:

> The usual signs which herald the approach of hurricanes were not present in this case. The brick-dust sky was not in evidence in the smallest degree. This feature, which has been distinctly observed in other storms that have occurred in this section, was carefully watched for, both in the evening of the 7th and the morning of the 8th. There were cirrus clouds moving from the southeast during the forenoon of the 7th. [We call attention to this fact, which is an excellent confirmation of what has been stated in Chapter II of this second part.]
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> A heavy swell from the southeast made its appearance in the Gulf of Mexico during the afternoon of the 7th. The swell continued during the night without diminishing, and the tide rose to an unusual height when it is considered that the wind was from the north and northwest. About 5 a. m. of the 8th Mr. I. L. Cline, observer, called me and stated that the tide was well up in the low parts of the city, and that we might be able to telegraph important information to Washington. He, having been on duty until nearly midnight, was told to retire and I would look into the conditions. I drove to the Gulf, where I timed the swells, and then proceeded to the office and found that the barometer was only one-tenth of an inch lower than it was at 8 p. m., observation of the 7th. I then returned to the Gulf, made more detailed observations of the tide and swells, and filed the following telegram addressed to the central office at Washington: "Unusually heavy swells from the southeast, intervals one to five minutes, overflowing low places south portion of the city three to four blocks from beach. Such high water with opposing winds never observed previously."

The direction of cirrus clouds coincident with the direction of the swell, and both making with the direction of the steady wind and lower clouds an angle of 90° to 120°, together with the slow descent of the barometer, which began to fall on the 6th, could have been taken as a most trustworthy sign of a coming storm just thirty hours before the center reached Galveston. The swell began to be remarkably felt when the center was lying about 350 miles from Galveston.

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[1] Boletin Mensual, 1900. Manila, 1901, p. 157.

[2] Monthly Weather Review, September, 1900, Vol. XXVIII, p. 372.

Fr. Froc, after having enumerated numerous observations which prove that the swell which was noticed in the anterior semicircle of the "Iltis typhoon" came from the direction of the center and was felt at a great distance, says:[1]

> It is quite clear that the point in question is not a local accident but a general fact and pertains to the constitution itself of the cyclone; all along the coast of China from Foochow up to Shanghai, in the Yellow Sea and the Sea of Japan as well as to the south of Corea and off the Goto Islands, at 500 miles at least from the center, a very sensible swell is observed in the semicircle situated in front of the trajectory. Is this same phenomenon reproduced in the rear, after the passage of the center, at a distance equal to that just stated? Observations are wanting for such an assertion, and moreover the question is of secondary utility from the special point of view of the forecasting of a typhoon. But from a practical point of view and to remain in the front semicircle, it clearly appears anew that one of the first indications forerunning the approach of a cyclone is the swell, an extraordinary swell not agreeing with the direction of the wind, and which by its presence points out not only the existence of a center of perturbation but also its bearing. It can not be too much recommended to the lookout men to have an attentive eye on the least variations of the swell, especially at the typhoon season. Undoubtedly, every slight undulation which ruffles the ocean surface must not be regarded as a forerunner of a great disturbance; but if their agitation has been observed and other signs subsequently are joined with it, this indication will be invaluable as permitting more complete solution of two questions: Where does the danger lie? and What is its importance? because the swell comes from the center and in general it must be propagated further, and consequently be felt sooner according as the causes of perturbation working at the center rage with greater energy.

Some modifications which the swell of the cyclone undergoes on the coasts of the Philippine Archipelago.—We have already called attention to the fact that the swell, if it meets serious obstacles, turns from its original direction. It then takes a direction which must differ from that which exists at sea. It is impossible to lay down definite rules to determine the resultants of the various forces which depend on the direction of the track and on the positions of islands and continents. There are, however, some empirical determinations of several changes which the swell undergoes owing to the position of the coast lines, and which may serve the sailor as a guide. We take this opportunity of asking all sailors to keep a watchful eye upon this phenomenon, so as to be able to assist by collecting additional material.

The typhoon of September 9, 1897,[2] offers an excellent example of the influence of the coast-line upon the direction of the swell.

> The M. M. S. N. Co.'s steamship *Yarra*, Captain Le Coispellier, carrying the European mails to Yokohama, left Kobe on September 8 at 5.30 a. m. with heavy rain and fresh east to east-southeast breezes. At her departure the Richard barograph (corrected) indicated the reading 757 millimeters (29.80 inches), which is but slightly below the average on the south coast of Japan at this hour in the beginning of September. Once in the Kii Channel the *Yarra* soon met a heavy southerly sea which became more and more marked as she advanced; it was clearly the swell of the typhoon already alluded to above, but now its direction was diverted by the land. What precedes shows that the effects of the swell were felt on the south coast of Japan more than sixteen hours prior to the passage of the center at its greatest proximity to Oö Sima, that is to say, at an approximate distance of 580 miles. When rounding the Sino Misaki Cape, the appearance of the weather was so threatening that the captain thought it prudent to seek shelter under the Island of Oö Sima.

Already in 1896 Fr. Froc had called attention to this deflecting influence of land upon the direction of the swell. In "Typhoon Highways," after stating his conviction that the swells radiate from the center, he says (p. 34):[3]

> It must, however, be remarked that this indication is wanting rather often in the Channel, when the center lies to the east or southeast of Formosa. The great island acts then like a screen, and checks the primitive movement or at least turns it from its course. It is thus that the movement rounding the coast to the north of Tamsui can occasion a northeast swell at the northern entrance of the channel, and round South Cape can give rise to a south or southwest swell to the south of the Pescadores. We have several examples of northwest or southwest swells observed at Anping before these typhoons; besides we can not expect to see there a swell coming from any other direction than from the third and fourth quadrants. The wind freshening and the barometer falling for the Formosa Channel are surely, at this period of the year, the clearest sign of a disturbance in the south. What will be the intensity of the perturbation would be difficult to say in advance, and the rapidity of the barometric fall is not always a measure of the energy of the storm, at least to the north of its trajectory and fairly distant

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[1] Froc, "The Iltis Typhoon," pp. 13, 14.

[2] Froc, "The Typhoons of September 9 and 29," p. 6.

[3] Fr. Froc, "Typhoon Highways." Zikawei, 1896, p. 34.

from the center. What may be said again is that a captain steaming in these quarters and seeing the wind increase considerably from the northeast in the north part of the channel, from the northwest or west in the south part, must be on his guard if the barometer falls at the same time, or even if it does not rise. I repeat that if this wind were due to the high pressures of the north we should see the barometer rise.

When the nucleus of a typhoon is forming in the Pacific in low latitudes—for instance, between 5° and 10° N.—we believe it to be probable that an easterly swell will show itself on the east coasts of Mindanao, but a southeasterly on the east coasts of the islands situated in higher latitudes up to the north of Luzon. We say "we believe it to be probable" because, unfortunately, we can scarcely find anything with regard to this question in the observations from these parts. The parts of the ocean between the islands will likewise be visited by the swell; judging by the situation of Samar and the easternmost part of Luzon, the swell in the seas of the Visayas will come from the southeastward, as long as the center remains south of 14° N. The swell must especially come into evidence between the north of Mindanao and the south coast of Luzon. In Punta Santiago, the extreme southern point of the lower peninsula of Luzon, a southeast swell was noticed on September 11, 1897, when the southwest winds freshened up in Davao owing to the influence of a cyclone which four days later crossed the central part of Luzon. On this day the center of the cyclone was far to the southeast of the station Punta Santiago.

If the center of a cyclone is near the fourteenth degree of latitude, and not too far from the Archipelago, a swell is also generated in the southern China Sea, which at first comes from the west, but later on from the southwest; the swell retains this direction if the cyclone is crossing Luzon, and even after it has traversed the island. The observations made at Punta Santiago during the typhoon just mentioned offer an excellent example of this. On the 11th of September, the center being then almost 600 miles to southeast of the station, a swell from the southeast was running; on the 14th the center was east-northeast of the station and the swell from west. When the center reached Luzon, on the 15th, a heavy southwesterly sea was prevailing, being felt even on the west coast, where it wrecked the merchant steamer *Taal,* with considerable loss of life, in sight of Corregidor.

The same phenomena as at Punta Santiago appear generally in that part of the China Sea which is bordered by the west coast of Luzon from the fourteenth to the eighteenth degree of latitude, except that the sea does not run from the southeast. The ocean usually remains quiet until the vortex of the Pacific cyclone is near the east coast of Luzon, when a swell from the third quadrant appears and increases as the center approaches. If the center is in high latitudes the sea runs usually from the south; but it is south-southwest if the center—as was the case in June and July, 1897—is stationary at the eastern entrance to the Channels of Bashi and Balingtan. If the center is in a position to exercise its influence upon the south of the China Sea without being therein checked by the Archipelago, as happens when it moves toward the Formosa Channel or crosses the China Sea itself, the cyclonic swell is propagated freely and to great distances. It is worthy of note that on October 14 a northerly swell was observed at Cape Bolinao; this originated in the center already frequently mentioned which had crossed Luzon on October 9 and 10, 1896. It often happens, however, that while a cyclone after having crossed Luzon is taking its course through the China Sea, the southwest swell still lasts for some time, at least as long as the typhoon is still situated at a distance from which it can influence the west coast of Luzon. This was the case, according to the observations from Punta Santiago and Cape Bolinao, when the cyclone of July 28, 1896, had crossed the island and reached the China Sea.

From what has been said we draw the following conclusions: (1) If a cyclone has reached Luzon from the Pacific Ocean the direction of the swell in a large part of the China Sea is to a certain degree directed toward the center.

(2) The swell at the rear of the typhoon in the China Sea frequently does not come from the center.

We may explain the first assertion by the fact that the coast line of Luzon, which runs as a whole from north to south, destroys the driving power, as it breaks the waves which for the greater part are produced by the movement of the center. At such a time the centripetal force alone, resulting from the great difference in pressure between the vortex and the surrounding zones, exercises its influence over the China Sea.

The second assertion is explained either by the fact that the conditions necessary to generate a swell do not exist at the rear, or else—and this seems more probable—that we have to deal with the effect of the great currents which must be formed in the Channels of Bashi and Balingtan, if the swell of the cyclone really makes its influence felt on all sides. The masses of water will rush especially toward the side on which these channels open, since there they do not meet with obstacles. The waves which have their origin in the channels and which are, for instance, driving toward the west opposite Luzon, combine with waves which originate along the shore owing to the immense drain of water caused by the vortex. They give as a resultant a swell from the third quadrant for the time during which the typhoon is crossing the China Sea.

Damage caused by the swell along the coast.—It is not difficult to imagine the devastation which the swell of the cyclone causes around the center and near the coast. Reid quotes an example of this kind from the memoirs of Piddington, which is not the less interesting from the fact that it happened over a century ago.[1] Captain Webb, of the East Indiaman *London,* thus tells his experience:

> On our first arrival on the coast of China off Macao, July 17, 1780, after my packet was delivered to the supercargoes there, a typhoon came on, which had very nearly demolished us. At 4 p. m. our best bower cable parted, and the ship cast inshore; but by setting all the sail I could, I just weared her clear of the land, and as the wind was east-northeast we stood out to the southward under our courses, and at 6 had the Ladrones bearing northeast. At 8 the wind flew round to southeast and blew the hardest gale I ever remember. We were then in 20 fathoms water, and not being able to make any more way out, our sails all blowing to pieces, we looked upon our destruction as inevitable without a particular act of Providence, for we were driving on a lee shore. At 12 at night the wind flew to the south, its violence still continuing, and we found the ship shoaling her water, so that every soul on board was preparing for death. At daylight we were in 12 fathoms water, with the sea, which was as much mud as water, breaking entirely over us. We then threw some of our guns overboard and cut away the main and mizzen masts, and by the time we had cleared them we were in 3 fathoms water, the land only about a quarter of a mile distant. We immediately cut away the foreyard, and let go the sheet anchor, which by the mercy of God brought us up; and as the ship touched the ground abaft, it eased her to the cable, or I am well assured the *Royal George's* anchors and cables would not have held her. We then instantly let go our spare anchor with a new cable, which parted as we were veering it out, so that we had no other left. About 9 a. m. the gale abated. In the evening we hove up our sheet anchor, when we found the cable stranded. What saved the ship was the having all our guns housed, her ports in, and topgallant masts down on deck, before the gale came on. Our drift in the gale was amazing. I imagined it at first only about 50 miles, but to my astonishment when the gale was over I found myself as low down as Hainan, within the westernmost island, about 3 leagues from the continent. I must have passed in the night quite close to a rock that bore south by west when the ship brought up. The Chinese told me that every vessel that was that night at sea perished except mine; and that they had lost all their junks and boats round the whole country, and were certain not less than 100,000 people had perished in the storm.

One more example: The wave and swell of the typhoon sadly famous through the wrecking of the *Taal* were very formidable. According to a Hongkong periodical,[2] the center of the typhoon passed Hai-Kow, on the Island of Hainan, on the morning of September 18, 1897. Long before the center had reached the place the swell began to increase and the sea to rise to such an extent that, although with the usual high tides, the town was 2 meters above the level of the sea, some of the streets at the time of the highest water level were 5 or 6 feet under water.

Damage caused by the hurricane wave.—The damage done by the hurricane wave is much greater and more terrible than that usually inflicted by the wind at sea or on land. The effects of the wave are especially disastrous when it breaks over a low shore. Fr. Viñes writes on this subject in "Apuntes Sobre los Huracanes de las Antillas," p. 193:

> Whenever the meteor passes from the sea onto the land, dashing the cyclone wave against the shore, the velocity of the storm's advance has a powerful effect in raising the level of the water, since the movement of the

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[1] "Progress of the Law of Storms," Vol. II, p. 181.

[2] Hongkong Daily Press, September 27, 1897.

cyclonic wave in the direction of advance of the vortex exerts an enormous force at the moment of impact, checking the receding wave and thus forcing the water up to a still higher level. This was doubtless one of the reasons why the cyclone of 1875 wrought such terrible havoc by its waves when it entered the island (namely, Cuba) and afterwards when it reached the continent on the coast of Texas. The same explanation accounts also for the fact that during the hurricane of October, 1876, the rise of the sea was much greater on the south coast where the cyclone entered than was the case on the north coast where the vortex left the island.

As the last-mentioned cyclone reached the coasts of Texas the sea rose, according to American newspapers, 20 feet above its usual level. The devastation was complete, 176 persons fell victims to the floods, and the fields, covered and ruined by the waves, were transformed into a vast lake.

The following passage, taken from Eliot's "Handbook of Cyclonic Storms in the Bay of Bengal,"[1] gives a good idea of the effects of the hurricane wave:

The most remarkable feature of the Calcutta cyclone of 1864 (October 2–6) was the storm wave. It was nearly full moon on October 5. The storm wave arrived at the mouth of the Hooghly a little after 10 a. m., high water being at about noon. The storm wave apparently advanced more slowly up the Hooghly than the ordinary tidal wave, and hence at Calcutta the storm wave was only about an hour in advance of full tide. The wave therefore occurred under conditions favorable for producing a very large effect.

The enormous accumulation of water in the northwest angle of the bay when the storm center was crossing the coast was very strikingly shown by the experience of the ship *Martaban*. She lay at anchor in Saugor Roads on the evening of the 4th, when it was blowing a strong gale. At 5 p. m. of the 5th the wind had increased to a hurricane and the ship began to drag her anchors. The fore end topgallant masts were carried away at 9.30 a. m., the mainmast at 10 a. m., and the fore-topmast at 10.30 a. m., by which time the ship was a wreck on deck. The center shortly after passed over the vessel, and was followed by a terrific wind that blew for a short time. The weather began to abate at 12.20 p. m., and cleared up rapidly. As soon as it cleared up sufficiently to enable the pilot to ascertain his position, he found that the vessel was to the west of Jellingham sand, and had drifted over some of the most dangerous sands in the river without touching or shoaling any water. The lead was constantly used, and the ship never shoaled at less than 7 fathoms. The pilot hence estimated that the storm wave must have risen at least 40 feet to have carried him across those sands.

One point in connection with the storm wave is of great interest. It is very unlike the tidal wave, which rises gradually, and which only on favorable occasions gives rise to, and is accompanied by, a small sudden advance of a wave or wall of water or bore. In the case of the storm wave there is, for some time as the storm center approaches the shallow waters at the head of the bay, a large accumulation of water. This head of water finally gives rise to a sudden and overpowering advance of the accumulated mass of water up the river and an almost equally rapid inundation of the low-lying grounds near the seashore.

Of the terrible effects of this wave the following passages, taken from the same source, give some idea:[2]

The storm wave flooded the whole of the low-lying ground in the neighborhood of the Hooghly as far up as Akra in Kidderpore, and the lower reach of the Roopnarayan River to above Koila Ghât, sweeping all before it by the suddenness of its rush and by the immense volume of water. The following gives a brief account of the destruction of life in the submerged districts: Loss of life during the flood (approximate), 50,000; loss by disease due directly to the flood, 25,000 to 30,000; hence total loss of life directly and indirectly caused by the storm, 80,000.

There were, on October 5, 195 vessels in port (Calcutta), either at their moorings or at anchor in the stream. * * * Of the whole number only 23 were uninjured on the morning of October 6; 39 were damaged but slightly, 97 damaged severely, and 36 were totally lost or had suffered so severely as to become, constructively, wrecks.

The Peninsular and Oriental Company's steamer *Bengal*, 2,185 tons, was landed high and dry on Shalimar Point, where she remained a conspicuous object for more than two months, when she was at length restored to deep water by cutting a dock around her, and towing her out at vast expense.

We shall also quote as an illustration the Yap cyclone of January 20, 1895, which has been described in an essay written by P. Fr. Antonio de Valencia, Superior of the Capuchin Missionaries on that island:

On January 16 there were indications of a cyclone in the north; on the 17th the force of the wind and the masses of clouds increased, but no rain fell; the 18th passed in a similar manner. On the 19th the cyclone continued with rain and an overcast sky; at 10 p. m. the force of the wind increased greatly, direction north-northwest; the sea was very high. By daylight on the 20th the force of the wind increased still further, the sky

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[1] Second edition, Calcutta, 1900, pp. 215, 216.

[2] Ib., pp. 216, 217.

> was overcast, it rained at times; at 8 a. m. the wind from north-northwest veered to west-northwest, but after an hour it backed again to north-northwest. At this time (sixteen hours before the arrival of the center) the sea had already risen higher than the usual limits of the highest floods of the year; the waves broke over into the forest. At 9 a. m. the waves had already reached the walls of our church and of our house and continued to rise incessantly; at 10 a. m. the water had got up to the first story, and at noon the church and presbytery were in ruins. During the whole rest of the day the sea was frightful; this can not be described, and I can only say that the cyclone wave came on and poured into the first story of the presbytery of which the partitions were already gone. The sky remained entirely overcast, and it rained without intermission; the wind was north-northwest, increasing still in the afternoon. After sunset it exhibited such a force that it blew down trees and lifted and carried away the iron roofing of the houses of our colony; thus it kept on till 10.30 p. m. About this time the wind, which had been blowing with hurricane force for the last twenty-four hours, commenced to abate. The calm lasted one and a half hours. At 12.30 a. m. the wind began to blow with still greater force than previously, uprooting or else breaking many trees, and overturning the native huts. The south-southeast wind, which took the place of the north-northwest, destroyed all that its predecessor had left standing. By daybreak (on the 21st) the wind lulled down; there was a comparative calm at 7 a. m., the sea having returned to its old level.

We will adduce another more recent instance. When we discussed in the papers of May 20, 1896, the principal features of the cyclone which made its influence felt in our Archipelago from May 10 to 18, 1896, we wrote as follows:

> Finally we must not omit to mention that we have ascertained on good authority that the height of the sea at Manila was so extraordinary as even to surpass that attained in 1882 during the passage of the most terrible typhoon which crossed the Archipelago during the last forty years. The force of the wind alone does not seem to suffice for an explanation of this phenomenon, because it did not exceed 61 kilometers per hour, and even during the squalls which occurred at intervals it reached only 24 meters per second. Now on other occasions the gale has frequently been fiercer without accomplishing such surprising results. It is clear, therefore, that on this occasion several factors coöperated which but rarely work together. First of all on this day high water occurred at noon, at the time when the southwest wind, increasing in force at the entrance, was blowing into the wide bay; furthermore, at this time the typhoon was recrossing our meridian in the north, so that the swell of the cyclone was bound to develop to its utmost height, while the wave of the cyclone poured forth upon the west coast of Luzon, and thus greatly influenced the height of the water level on the coasts. Besides this the center had remained for several days in the China Sea, and had developed there its internal energy in proportion to its slow advance and had generated an immense cyclone wave in its center with which it then descended again from the sea on Luzon. Manila was, therefore, this time on the front side of a typhoon advancing from the sea, which was not the case in 1882.

The cyclone of August 16 to 18, 1879.—Some time after the occurrence "La Voz Montañeza" and "Diario de Cádiz" published a graphical account of the experiences of the trans-Atlantic liner *Ciudad de Santander* in a typhoon which it encountered on its voyage from Habana to Spain in the latter half of August, 1879. The description comes from the pen of an eyewitness, Señor La Rigada, first lieutenant, Spanish navy:

> We left the harbor of Havana on August 15 at 6 p. m. with apparently fine weather, there being not the slightest indication of an impending tempest. Twenty-four hours later we had reached Jupiter, the point at which the Bahama Channel is supposed to end. On the evening of that day—that is, August 16—we steamed ahead with a smooth sea and a light northeast wind, the sky and the horizon being covered with an abundance of cirro-cumuli and the barometer standing at 769.61 millimeters. Shortly after nightfall, however, we encountered a cross sea from southeast,[1] which by midnight became boisterous, and the northeast wind freshened. Barometer 767.07 millimeters, thermometer 27.2° C. The sky continued to look bad; the fresh and squally wind, as well as the waves due to it, came from northeast, the heavy swell from southeast.[2] The horizon looked ominous, the whole sky was hidden by a gray covering of clouds. The next morning the barometer showed 767.07 millimeters, the thermometer 28.9° C. During the forenoon of the 17th the northeast wind gained in force and the swell from southeast became heavier. The weather looked decidedly threatening. At noon of the same day the weather was quite thick, a fine rain came down with violence, the gray clouds hung low in compact masses and moved swiftly in a westerly direction; the wind blew in gusty squalls from northeast with a tendency to veer toward the east; there were very heavy swells from the southeast crossed by the waves caused by the wind; the heat was suffocating and the whole aspect of sky and ocean indescribably ominous. Barometer 759.45 millimeters, thermometer 30° C.

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[1] The hurricane swell was, therefore, observed about twenty-three hours before the ship entered the vortex. Supposing the velocity of the storm to have been 18 miles, the vortex was then at a distance of some 420 miles from the ship.

[2] The writer clearly distinguishes between the hurricane swell and the waves caused by the wind.

The wind continued to stiffen, blowing a hard northeast by east gale at 4 p. m. There was, of course, a corresponding sea, besides the boisterous towering swells from southeast. The barometer falling continually registered at this hour 746.75 millimeters, while the thermometer showed 31.1° C., the heat making itself felt intensely. The covering of clouds very dense, low, and threatening; thick, fine rain; the outlook exceedingly limited owing to the darkness. Between 4 and 5 o'clock the wind increased and finally blew with inconceivable fury; the low-moving clouds seemed to strike the mastheads; raging seas broke over us from different sides [1] and the thick, fine rain made darkness complete. During this hour the barometer fell from 746.75 millimeters to 723.89 millimeters at 5 o'clock, while the thermometer rose to 32.2° C. There could be no doubt the vortex of the hurricane was very close at hand and the rapid descent of the mercury indicated the rapid advance of the cyclone, which prepared to make us feel its full fury. Shortly before 5 o'clock, in order to avoid serious damage, we changed our course to east-southeast, thus receiving the impact of the seas coming along the trajectory, which were the highest and simply irresistible, slantingly on our starboard.

At 10 minutes past 5 a sudden calm fell upon us, the barometer showing 721.35 millimeters, the thermometer 33.3° C. * * * On penetrating into the vortex the furious east-northeast wind had suddenly left us. For two or three minutes we still heard its howling, then reigned silence all around us.

There, within this terrible circle, the waves, seething, towering, of immense bulk, broke over us from every side, each one placing the ship in imminent peril. But skillfully guided she fought bravely with the aqueous mountains.[2] The passengers remained very quiet in their cabins, praying to God that He would check the fury of the elements, while the ship's crew redoubled their labor in face of the danger, now stopping the leaks through which the water poured into the hold, now securing the boats, which the sea threatened to wash away, obeying the orders of their officers with great promptitude. The compass needles swung to and fro in such a manner that it would have been impossible to steer by them. The gray sky grew lighter here and there, and now and then the sun broke through for a moment as if to illumine the scene of horror. The heat was stifling; a number of birds of various kinds and sizes fell upon the deck either stunned or killed by the destructive whirlwind. The barometer continued falling, from 721.35 to 716.27 millimeters; the rain had ceased, and only the waves in wild confusion and rage continued fighting their fierce battle in the midst of that dead stillness. True, the wind was terrible and destructive, nevertheless we longed for it, preferring its companionship to this dread, oppressive silence.

Ten minutes after entering the vortex we heard a distant roar coming from the third quadrant; it grew louder and louder and suddenly the steamer trembled under the onslaught of the howling south-southwest squall which really seemed to be the wrath of heaven. All the elements appeared to be unchained. * * *

We will close our enumeration of observations of hurricane waves with a very remarkable instance of such a wave, described in a detailed and interesting account[3] of the ravages caused by the terrible cyclone which toward the middle of the month of October, 1897, laid waste the central portion of the Archipelago, leaving on all sides marks of its destructive fury in the form of a great number of wrecked ships, devastated estates, and homes rendered desolate by death.

On the 12th day of this month of October, 1897, there passed over this locality (Tacloban, Leyte) a cyclone accompanied by a hurricane wave, the effects of which were so destructive that they produced a veritable hecatomb, both in this capital and in other pueblos of the island.

This pueblo of Tacloban has been converted into a heap of ruins; the few houses that are left standing are in a lamentable state on account of the damages suffered; some threaten collapse with imminent danger of causing new personal injuries in addition to those that occurred by reason of the said meteor. * * *

The writer then describes in detail the other phenomena which accompanied the storm, stating among other observations that from 4 o'clock a. m. until 1 p. m. the barometer fell 32 millimeters:

At 11 a. m. the barometer registered 728 millimeters, the wind showed a tendency to veer toward the first quadrant. Such was the intensity of the wind accompanied by a great increase of the tide—owing doubtless to the hurricane wave—that at 11.15 a. m., after we had already abandoned the highest and most protected portion of the archives, where the water stood waist deep, the constantly rising flood made it imperative to abandon the capitania, a building of board and nipa construction, in order to save the lives of those who were under my orders from the impending catastrophe. By this time the building was already half washed away. This saving ourselves was effected with the greatest difficulty, for on account of the strong current coming from the sea it was impossible to reach the administration building. These were moments of great anxiety; an attempt at reaching that building simply meant risking our lives. In this predicament I finally decided to follow the direction of the current and thus reached a tree in the interior of the pueblo where, not without great effort, I succeeded in saving my life. The men under my command were in a similar situation. The water continued to rise rapidly and soon only the nipa roofs of the "bahais" (native dwellings) appeared above the flood, which maintained a height of 3 to 4 meters. In this critical situation we remained until 2.15 p. m. At this hour the water began to recede, owing doubtless to the change of the hurricane wind to southeast, and I was able to climb down upon some pieces of timber, relics of destroyed houses, which, drifting about, had formed a kind of raft, by means of which I intended to reach the only house of solid construction which had remained standing in the neighborhood. In this I happily succeeded, and also the others saved themselves by swimming to the same house.

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[1] The same phenomenon, though of less intensity, was noticed on board the French cruiser *Isley*. Cf. p. 165.

[2] The hurricane wave.

[3] Report of Señor Don Joaquin Fontan to Admiral Don Patricio Montojo, commanding the Philippine squadron of the Spanish navy.

This formidable rise of water I attribute exclusively to the hurricane wave which, entering the harbor by the mouth of the bay of San Pedro and San Pablo, united with the waters of the narrows of San Juanico and those of the harbor. The latter is well sheltered, since it is surrounded by mountains on all sides except the one on which lies the town, which is built on a narrow, projecting strip of low land. This makes it clear how the flood could attain so great a height, the site of the pueblo being the only outlet for the accumulated masses of water. The inundation was the principal cause of the great loss of life which, judging from reports received by the governor of the province and the captain of the port, is truly appalling.

At 3.30 p. m., although the water was still knee deep, I went to the administration building, the residence of the governor, and we decided to go round the town together with the captain of the civil guard, and try to ascertain what damage had been done by the flood and to render what help was possible under the circumstances. * * *

At 6 p. m. I took the barometer reading, which was then 755 millimeters; the mercury had, therefore, risen considerably and it continued to rise until 12 o'clock midnight, when the reading was normal. From the data received from the "subdelegado" of marine at Tanauan, a small town 7 miles to the south of this place, I find that the vortex of the typhoon had a direction approximately west-northwest. The barometric minimum of 722 millimeters took place at 12.40 p. m.

This typhoon, which placed the southern provinces of Luzon in great danger, was felt at Manila on the morning of the 13th with violent gusts and squalls from the first and second quadrants. On the morning of the previous day, October 12, the Observatory had announced the existence of the storm in the following bulletin:

> The fall of barometers in the southeast announced yesterday increased notably. There is a depression southeast of Manila. The barometers throughout the island continue to fall. Here there are at present winds of variable force, gusty at intervals and accompanied by rain squalls.

The cyclonic wave of the Galveston hurricane, September 8, 1900, is another very recent and terrific instance. (See United States Monthly Weather Review, Vol. XXVIII, September, 1900.)

Application of the theory.—The hurricane of October, 1897, is one of the most suitable of all which came under our notice for the study of the nature of the hurricane wave and cyclonic swell. In conformity to what has been said concerning the nature of the hurricane wave it is easily understood that on the high sea the elevation of the mass of water in the vortical region and in the whole interior portion of the cyclone above the level of the sea in the exterior regions must be proportional to the amount of the atmospheric depression and to the greater or less steepness of its barometric gradient; so that if, for instance, on the outskirts of the typhoon there should be a pressure of 760 millimeters and in the central region—as in the case under consideration—of only about 700 millimeters, this want of atmospheric equilibrium will produce a proportional disturbance of the equilibrium of the water. The effect of this disturbance can easily be calculated from the differences of pressure in the various regions. For if with the mercury column indicating 760 millimeters pressure the height of a corresponding column of water would be about 10.3 meters, an excess of 60 millimeters pressure can sustain a column of water 0.8 meter high. Therefore, the vertex of the hurricane wave had a maximum elevation of some 0.8 meter, if we take into consideration only the inequality of atmospheric pressure. The slope of this small hill corresponded, of course, to the barometric gradient within the interior zones of the cyclone. The form of this mass of water was that of a conic frustum with eliptical bases. The smaller ellipse was formed by the vortical region and the larger by the extreme dimensions of the cyclone. To obtain some idea of the quantity of water which formed this wave it will suffice to give the approximate values of the bases and the height of this immense truncated cone. At 8 o'clock a. m. of the 12th the major axis of the lower elliptical base, determined by the isobar 748 millimeters, was equal to about 277,000 meters, the minor axis of the same base to 68,000 meters. On the other hand the major axis of the vortical elliptic region, determined by the isobar 700 millimeters, may have been about 62,000 meters, while the minor axis was certainly not less than 31,000 meters. The height of the frustum was, as has been stated, about 0.8 millimeter. By Simpson's formula (reduced) we can express the volume:

$$V = \tfrac{1}{6} a \ (B + B^1 \ B + 4 \ S)$$

Or, even better, by the ordinary formula for the volume of a conic frustum:

$$V = \tfrac{1}{3} a \ (B + B^1 + \sqrt{BB^1}),$$

In which formulas a = the height of the frustum, B and B^1 the lower and upper bases, respectively, and S an intermediate section parallel to the bases. If we substitute the given values in the formula the volume of the liquid mass which accompanied the cyclonic vortex when the isobar 748 millimeters reached the Archipelago is found to have been, approximately, 560,487,500 cubic meters.

Leaving aside intricate calculations as being little suited to the scope of our discussion, it will be enough to consider the part of this liquid mass which in consequence of the advance of the vortex successively struck against the open coasts of Samar and Leyte. The height to which the water level is raised is proportionate to the velocity of translation of the mass of water; to the greater or less resistance of the coasts, which in turn depends upon their conformation and their orientation with respect to the direction of the vortex; to the velocity of the superficial currents of the locality along the component corresponding to the direction of the hurricane wave; and finally to the action of gravity at the moment when the mass breaks up into waves. Hence it follows, theoretically speaking, that other conditions being equal the height of the hurricane wave when breaking over the coasts was necessarily greater (1) on the open coasts whose line of orientation was perpendicular to the trajectory of the cyclone, especially if besides this they offered insurmountable obstacles in the form of mountains or cliffs situated near the shore; (2) on the open coasts in closer proximity to the passing vortex; (3) in case of some obstruction against the force of the translatory movement and the impetus of the superficial cyclonic currents, the height would diminish in proportion to the influence of the obstruction. This supposed, the following simple formula will give some idea of the pressure exercised by the water against the coasts and of the height to which it would rise:[1]

$$P = (1 - \cos \alpha) \frac{V}{g} Q y$$

In which P = pressure exercised in kilograms, α = angle of inclination of the coast to the horizon when the sea is at its mean level, V = the velocity of the water in meters per second, Q = quantity of water expressed in cubic meters which each second reaches the coast, and y = weight of 1 cubic meter of water—that is, 1,000 kilograms.

In case of an insurmountable obstacle, such as a high cliff or mountain near the shore, etc., we may consider $\alpha = 90°$, the quantity of water which strikes such an obstacle being constant. In case of obstacles more or less surmountable, α will have different values according to their greater or smaller inclination. The formula shows that the maximum effect is obtained when the forces strike perpendicular to the coast. That the effect of these forces may be better understood we represent in the adjoined figures, 7 and 8 (Pl. XLVI) a vertical section of a coast opposing an insurmountable barrier to the waves. In both figures the horizontal lines represent the water at normal height, while the line *nm* shows the height above sea level of the hurricane wave under the sole influence of the forces which dash these masses of water against the shore. Fig. 7 illustrates the effect of an impact of this wave against the cliff, and fig. 8 shows the height attained by the sea (*nm'*) by reason of the *constant action* of the cyclonic forces, which lasted while the region of vortical calm and the zone of destructive violence—that is, of great barometric gradient—passed in a direction more or less oblique to the coast line.

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[1] See "Aide Mémoire de l'Ingenieur," by Huguenin, pp. 208, 1121.

Plate XLVI.

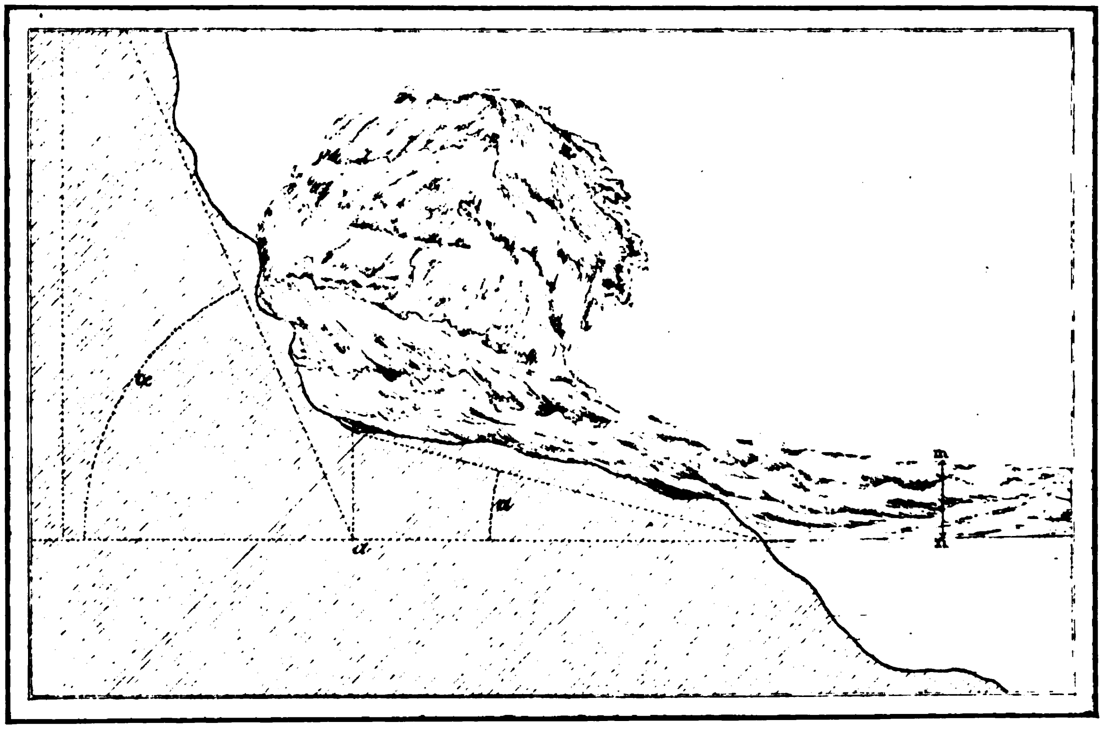

FIG. 7.

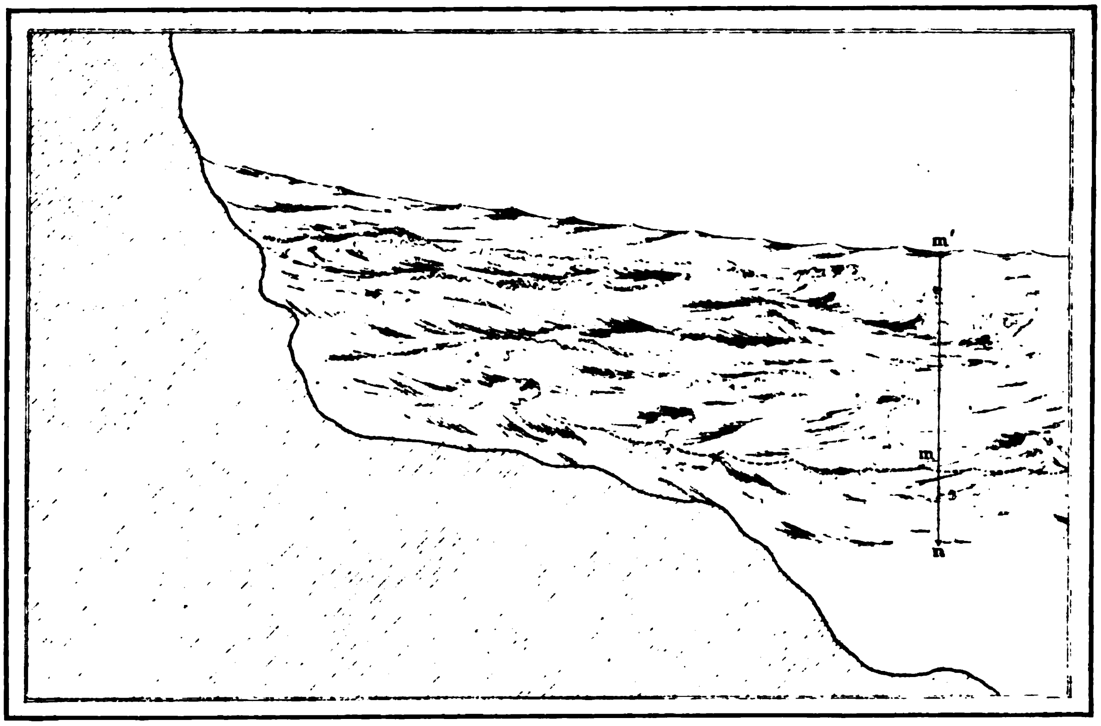

FIG. 8.

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All facts concerning the flood of October 12 can be fully explained under the supposition that it was a hurricane wave, and the effects observed can be deduced from the formulas given. We might, therefore, rest satisfied that we have sufficiently established the true character of the wave. In view, however, of the great importance of the matter we will go further and prove that it can not have been of seismic or geological origin, which explanation would be the only other alternative to which a superficial study of the phenomena could lead.

Difference between the hurricane wave and those waves which are produced by geological or seismic phenomena.—By geological or seismic phenomena we mean all effects recognized as resulting from some interior or endogenous movement of the earth, of whatever nature they may be. We say geological or seismic because we are not ignorant of the fact that immense collisions of forces on the surface of the earth, for instance, the pressure of the hurricane wind against mountains, the perturbation of the sea, especially the impact of the angry waves against an obstacle, extended subsidences of land, etc., can produc microseismic and even small sensible local movement—as was distinctly observed at Manila during the passage of the vortex of the typhoon of 1882, and in other localities on similar occasions. But it is clear that these movements are the effect rather than the cause of the wave.

In order to prove that the wave of October 12, 1897, can not have been of any other than cyclonic origin it suffices to inquire into the recorded facts and compare them with those observed in cases in which the wave was evidently of seismic origin, or the effect of geological movements—that is, of the upheaval or subsidence of land, etc.

Four principal properties characterize the hurricane wave which are not observed in waves of noncyclonic origin:[1]

(1) The hurricane wave gathers volume gradually, with more or less rapidity, but without perceptible reflux. It maintains a great height for a long time, and then the sea returns to its former level.

(2) The hurricane wave occurs without perceptible earthquake shocks, either antecedent or subsequent, or at the moment of its invading the coast.

(3) The hurricane wave invariably follows the cyclonic trajectory.

(4) It is observed simultaneously with barometric depressions.

These characteristics do certainly not resemble the effects of geological or seismic phenomena. Some of them might, indeed, accidentally coexist with them, but others positively exclude them.

Now let us examine the well-known instances of waves of undoubtedly seismic origin[2] for the above characteristics.

(1)' In none of the cases of seismic waves recorded by authors has the wave been observed to gather its volume gradually and to remain at a high level for any length of time; but the seismic wave has invariably presented itself as a rapid flow and ebb, unless, indeed, the latter was impeded, in which cases the depressions along the seashore were converted into lakes or marshes. The most celebrated cases of seismic waves recorded in modern times and which have been minutely described are: That observed in Callao (Peru), October 28, 1746; of Lisbon, November 1, 1755; of the coast of Calabria, February 5, 1784; that which occurred in Chile, February 20, 1835; another in Peru, August 13, 1868; that of Java, in 1883; several instances recorded in the history of Japan, especially the one of 1896, and that of Zamboanga, September 27, 1897.

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[1] The facts recorded in the pamphlet "El Baguio de Samar y Leyte," Manila, 1898, pp. 14–32, may serve as confirmation of our assertion.

[2] Meteorologic, seismic, and geological authors are divided in their opinions concerning the cause of the extraordinary noncyclonic waves. Some maintain that they are the effects of shocks or submarine earthquakes; others, of upheavals at the bottom of the ocean; others, of depressions of extensive areas either in the sea or on the continents; others again hold that these waves are due to causes which are not endogenous to the earth but exist in the atmosphere as, for instance, electricity. Laying aside all these views, which can hardly be said to exclude each other, we call seismic waves all those extraordinary waves which according to common opinion are not cyclonic.

Callao was razed to the ground by a passing wave, which rose to the height of 27 meters,[1] at the time of the terrible earthquake of Lima.[2]

After the earthquake which, according to historians, buried 60,000 victims under the ruins of the Portuguese capital, the sea first retired and then swept over the coast and the unfortunate city in a wave of 15 meters' height. The flood immediately receded with violence, devastating the shores of Portugal and southern Spain. At Cadiz it reached a height of 18 meters, thence it crossed to Africa; two hours and a half after its appearance in Lisbon it beat upon the Island of Madeira, where it had a height of only 4.5 meters. The same wave made itself felt in Ireland and even on the other side of the Atlantic, reaching in the Lesser Antilles a height of 7 meters. Everywhere it had the character of a violent flow and ebb. The earthquake of Lisbon, where the first wave was experienced, was merely an indication of the commotions which caused the waves.[3] The authors who refer to the damages done by these floods all agree that the first wave was the highest and most violent, the successive waves decreasing in altitude and energy—precisely the contrary of what happened in our case of October 12, 1897.

During the earthquakes which convulsed Calabria, in 1783, the coasts were invaded by a series of waves which swept before them the houses, trees—in short, everything they met with. By the force of the first wave were thrown ashore the fishing smacks crowded with people who, on perceiving the first seismic shocks, had fled to the boats, thinking thus to escape the dangers of the earthquake. The number of victims was 1,430.[4]

Of the earthquake of Chile, 1835, we have the description of the English captain, Fitz-Roy, an eyewitness. He relates that in the Bay of Concepcion the sea retreated, leaving dry the ships which had been anchored in fully 5 fathoms of water. But soon the sea returned with tremendous fury. At least twice this phenomenon was repeated.[5]

An eyewitness of the earthquake of Arica (Peru), in 1868, records how after the first shocks he observed that the vessels in the bay were carried out to sea with a velocity apparently of some 10 miles an hour, and how some minutes later, when the ebbing current ceased, an immense wave of some 15 meters' height arose and, dashing upon the shore with incredible violence, swept everything before it. This was followed by other waves, the sea surging to and fro with great fury.[6]

It is very probable that the destructive waves of Java in 1883 were partly due to geological causes, since large areas of land have disappeared from view, being now covered by the sea. The whole phenomenon had not so much the appearance of advancing and retreating waves as that of an invasion by the ocean.[7]

There are many cases recorded of seismic waves devastating parts of the Japanese coasts,[8] the chief ones of which are those of 869, 1601, 1741, 1751, 1804, and finally 1896. In all these instances earthquakes were perceived either in the regions thus visited or in the adjacent islands; moreover, in every case the first wave had the greatest energy, and was rapidly succeeded by others in the form of flow and ebb.[9] On a few occasions parts of the coast remained covered by water, a phenomenon of rather rare occurrence, which doubtlessly is due to subsidence of the respective regions.

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[1] "Le Monde Physique—Les Mouvements de la Mer," by Guillermin. Paris, 1885, p. 666.

[2] "Principes de Géologie," by Lyell, Vol. II, p. 188.

[3] Ibid, also "Le Monde Physique," p. 667.

[4] "Principes de Géologie," Vol. II, p. 172.

[5] "Principes de Géologie," by Lyell, Vol. II, p. 188; "Le Monde Physique," p. 667.

[6] "Année Scientifique," by L. Figuier, 13e année.

[7] "Le Monde Physique," p. 668.

[8] Taken from the Japanese journal, "Osaka Asahi."

[9] See "Hongkong Telegraph," June, 1896; "Japan Gazette," end of June, 1896; "Hongkong-Daily Press," July 4 and 22, 1896; "Comercio." of Manila, July 28, 1896—in which will be found descriptions of the famous wave of Yeddo (Japan) of June 15, 1896. These descriptions are translated from the Japanese papers.

More recent is the case of a wave which we may call geologico-seismic.[1] It made its appearance in the southern part of our Archipelago, and we referred to it above as the Zamboanga case. It will suffice to set forth some of its characteristics to show that it was of a nature totally different from that of the wave which accompanied the typhoon of Samar and Leyte.

(*a*) In Zamboanga, La Isabela, Jolo, Santa Maria, and the other places in which the wave of September 27, 1897, has been observed it showed a distinct flood and ebb—that is, several successive waves. It also was preceded, accompanied, or followed by earthquakes.

(*b*) In connection with the Leyte wave there was no notable earthquake shock[2] nor any elevation or depression of land either before, during, or after the wave. But all authors agree on this, that there is no instance of a seismic or geological wave without more or less intense earthquakes. Some phenomenal seismic waves have, indeed, been propagated to distances at which the seismic shock could not possibly be felt, but in every case the connection with an earthquake could easily be traced. To this category belonged the seismic wave of the earthquake of Lisbon, which we have already mentioned; but especially the wave which resulted from the earthquake of Japan, June 15, 1896. The latter was observed on the Hawaiian Islands, where it caused considerable damage,[3] and even reached Santa Cruz;[4] there was no trace of a shock in these places, but the rapidity with which the wave was propagated and the earthquake of Japan immediately preceding it did not leave any doubt as to its origin.

(*c*) The manner in which a cyclonic wave is propagated differs entirely from that characteristic of seismic or geological waves. The wave which struck the Island of Leyte, like every other cyclonic wave, advanced exactly in the trajectory of the cyclone and reached only the shores which were traversed by the destructive zone of the storm. The seismic wave, on the contrary, has no determined direction; it propagates itself in all directions. Moreover, it is very far from being of relatively constant energy; but, being most powerful at the point at which it is formed, it diminishes as it travels along, in conformity with the well-known laws of waves and also in proportion to the accidental resistances it has to overcome. The seismic wave caused by the earthquake in the south, on September 27, 1897, was observed in the whole Archipelago of Jolo, in the Calamianes, along the whole western coast of Mindanao, in La Isabela de Basilan, and probably in the whole north of Borneo.

(*d*) The cyclonic wave traveling with the vortical region, its velocity can not be greater than that with which the cyclone advances. The velocity of translation of the seismic wave is stupendous. In two hours and a half, according to some authors, the wave traveled from Lisbon to the Island of Madeira, a distance of 550 miles. That of Japan was felt at points as far distant as the eastern coast of Japan and even the western coast of America within the short space of twenty-four hours.

(*e*) There is another circumstance which makes all seismic or geological influence upon the wave of October 12, 1897, entirely improbable, namely, the fact that the energy of our wave was proportional to the atmospheric depression, while, generally speaking, seismic or geological waves preserve no relation whatever with the depressions of the atmosphere, a statement fully borne out by investigations of these seismic waves.[1]

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[1] We call this wave geologico-seismic, because we believe that it was the combined effect of both factors, earthquake and alterations in the level of the bottom of the ocean. On the day of the wave powerful shocks of earthquakes were felt in the Archipelago of Jolo, at La Isabela de Basilan, and over a great part of Mindanao; at the same time there appeared a new islet in the entrance to the Bay of Lubuan, northwest of Borneo, while a small existing island in the Jolo Archipelago disappeared.

We base our hypothesis concerning the double cause of the wave upon the following facts: (*a*) The propagation of this wave was very clearly distinct from that of the earthquake; (*b*) the phenomenon of successive waves was noticed for a relatively short time, while there were several strong shocks at different times during which no such waves were observed.

[2] There were a few slight shocks felt at Zamboanga on October 11 and 12, but we do not think that they can reasonably be connected with the wave in question.

[3] According to a report of the "Commercial Advertiser."

[4] "San Francisco Chronicle," June 16, 1896.

WORKS WHICH MAY BE CONSULTED IN CONNECTION WITH CHAPTER VIII.

Beehler. Relations Between the Barometric Pressure and the Strength and Direction of Ocean Currents.

Dove. Law of Storms, p. 296.

Fleuriat de Lange. Études sur la Météorologie Navale. Revue Maritime, 1865.

Froc, Rev. A., S. J. "Iltis Typhoon," p. 12.

Hoffman. Zur Mechanik der Meereströmungen an der Oberfläche des Oceans. Berlin, 1884.

Moore, Prof. Willis. What is a Storm Wave? Monthly Weather Review, 1901, p. 460.

Reid. Laws of Storms. London, 1849.

Romme. Tableaux des Vents, des Marées et des Courants que out été observes sur toutes les Mers du Globe. Paris, 1806.

Viñes, Rev. B., S. J. Apuntes Relativos á los Huracanes de las Antillas. Habana, 1877.

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[1] "La Seismología en Filipinas," by Rev. Miguel Saderra Masó, S. J., p. 120.

CHAPTER IX. OTHER INDIRECT PRECURSORY SIGNS.

We devote this chapter to a discussion of the remaining indirect signs of cyclones. However interesting they may be as meteorological phenomena, they are of but little importance as forewarnings. For, although some of them have close relations to the elements of the typhoon, this relation is neither sufficiently determined and known nor so characteristic and unvarying as to afford certainty or even a considerable degree of probability to the weather forecaster.

Is the anticyclone an indication?—Does an anticyclone always precede a cyclone, and is it for this reason an indication of its advent? An anticyclone, as we understand the word, is a region of high pressure, or a region with a pressure higher than normal, inclosing a center or a nucleus of highest pressure, from which the pressure decreases outward. In the anticyclone which likewise possesses a movement of progression, upper and lower currents appear; and these are contrary to those noticed in the cyclones. According to this definition, the area of high pressure which at certain seasons lies over Siberia would not belong to the anticyclones, for the high pressure which exists there is normal for the respective season, and besides this, its movement is extremely slow. This supposed, we answer the above question as follows:

(1) At least in the Philippine Archipelago and the surrounding seas an anticyclone does not always antecede a cyclone.

(2) Anticyclones sometimes appear without any disturbance of a cyclonic character or any depression following them.

(3) Great areas of high pressure have often been formed without the development of an actual anticyclone, and these were followed by cyclones.

(4) If cyclones follow each other at short intervals, which very often happens in these latitudes, neither an actual nor an apparent anticyclone will be developed.[1]

(5) If a cyclone appears after a succession of normal days it is generally preceded by a region of high pressure, which has, however, not always the character of the anticyclonic circulation. With regard to this subject we find the following in the Monthly Review for October, 1881:

> While this cyclone was moving across the Archipelago another was following from the Mariana Islands, which announced itself first on the 23d. The barometer had risen a little, but it did not reach the level which it usually shows at this time. With regard to this matter we would ask, In this case where is the anticyclone which is supposed to be necessary for the formation of every cyclone? How is it to be understood that one cyclone can form after the other, and the second should follow the first in its track, without there being found a single sign of the anticyclone anywhere? The barometer, it is true, rose slightly during the short interval between the two cyclones. But this rise was, in our opinion, by no means what it had to be if the theory of anticyclone possessed the importance assigned to it by some modern meteorologists. At first we thought this theory well founded, and actually employed it for the explanation of many facts observed before and after the passage of the storm; but we have come to the conclusion that it is impossible to reconcile it with the whole of the phenomena as observed here. The anticyclone showed itself only on rare occasions with the characteristics which usually precede or follow the hurricanes of the Atlantic Ocean.

What Fr. Faura said has been entirely confirmed in the sixteen years that followed. We by no means deny the existence of the anticyclone, strictly speaking, but we deny the essential and necessary relation between this phenomenon and the cyclone. This suffices to justify our statement that the anticyclone is of no importance as an indication, though we admit that in some instances it may precede an atmospheric disturbance.

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[1] An excellent confirmation of this rule is furnished by the typhoons felt in Luzon during the latter part of July, 1902. See Monthly Weather Bulletin for July, 1902.

Fr. Chevalier also in 1893 examined the question, whether it was true, as some suppose, that the cyclone is always preceded by an anticyclone, and whether it be possible eventually to base a prognosis upon it. He expresses his opinion as to this point in "Typhons de 1892," Shanghai, 1899, pages 63, 64, and 68, as follows:

> After minutely examining the barometrical curves from some stations, we are bound to reject this supposition as being without foundation as far as the typhoon of the 10th of October as well as that of the 21st of July, 1892, are concerned.
>
> In a word, it is not true that a higher pressure than the normal always precedes the arrival of a cyclone at a station, on the China coast at any rate. If, however, the barometer be actually higher before the typhoon arrives, this has at least frequently nothing whatever to do with the cyclone. It is, moreover, certain that a barometer which shows a reading somewhat higher than the normal is often not followed by a cyclone. A higher barometer by itself is therefore of no value whatever as being a prognosis for a typhoon. Still it would be a mistake if you were to come to the conclusion—as has been done—that I deny the existence of anticyclones. These areas of high pressure and their systems of wind, which have a contrary direction to those circulating around the depressions, very probably stand in relation to the latter. But this does not prove that an anticyclone must precede a cyclone; it does not even prove that a hurricane or a cyclone of a similar character must have an anticyclone for a companion.
>
> We do wrong if, without any proper proof, we propose to jumble up two phenomena which are so unlike each other as the cyclone which is of tropical origin and the depressions which have their origin in higher latitudes. An identity may possibly exist, but in order to establish this claim we require proofs, and these must first be collected. We may say that if the air rises in the interior of a cyclone it must necessarily produce an increase of the pressure in the vicinity of the cyclone. This is probably true, but this result is, perhaps, not so evident as to be noticed at first sight. Yet it is not our intention, in order to confirm facts, to deal with theories which are, or may be, frequently liable to discussion; we only wish to establish the facts themselves. This we propose to do with the aid of three typhoons of the year 1892, those of the 17th of August, 6th of September, and 23d of July.

Fr. Chevalier closes his investigation with the following words:

> Among the five principal cyclones of 1892 we found one only in which the preëxistence of an anticyclone can be maintained. But I have not been able to find out whether the anticyclone existed on the front, on the rear, or on the right or left semicircle of the typhoon, which depends upon it. We should greatly deceive ourselves if we considered a region of somewhat higher pressure with light winds, fair weather, and the character of an anticyclone to be an indication of the existence of a typhoon. But we should be still far more wrong if we thought these phenomena of high pressure to be indications of the fact that a cyclone will pass close by the place of observation.

The region of high pressure around the cyclone.—If we look at the construction of a cyclone it has the appearance as if a region of high pressure were surrounding the body of depression, and this has unsuitably been called an anticyclone. Unsuitably, because nobody can explain how there could be within this annular region an anticyclonic circulation since there is no high-pressure vortex or nucleus. In this zone the extraordinary readings are observed which the barometers occasionally attain before the descent due to the cyclone commences. We do not observe this ring of high pressure if the cyclones are following each other at short intervals, at least not on the front part. It is, nevertheless, possible that the whole chain of cyclones represents one large and prolonged region of depression, round which the annular region of high pressure exists; so that the individual cyclones of the chain are formed here under conditions similar to those under which secondary cyclones are often developed within the body of an extensive storm—that is, without a high-pressure zone surrounding them. It follows that a rise of the barometer above the normal level may lead us to suspect that there is an atmospheric disturbance; but in order to arrive at certainty we must pay attention to the other indications, for at the very best this sign by itself can only raise a suspicion.

The other indications, such as cirrus veil, halos round sun and moon, have been beautifully described by P. Viñes in his excellent work, "Apuntes Sobre los Huracanes de las Antillas," pages 166–169.

> **Cirrus veil.**—The blue of the sky becomes gradually overcast with a cirrus veil, even before the cirro-strati have made an appearance as indications. This veil is hardly noticeable at first, but it becomes thicker and

thicker afterwards until it forms a cirro-pallium. This is soon followed by a homogeneous and dark stratum of clouds at a lower level, nimbus, with continuous rain.

Whether or not the various phases show themselves in regular succession depends on the approach of the cyclone toward the place of observation, and on the distance at which the center is passing. The following is the regular order: The blue of the sky assumes at first a somewhat whitish hue, soon this changes into a clear opal color, which in turn is quickly replaced by milk white. Later on the cirrus veil becomes dense and homogeneous, assuming a dirty-white, ashen tinge. The color next changes almost imperceptibly to a dark leaden gray, giving the sky a heavy threatening appearance. The darkness increases, and next a fine continuous rain sets in, which is only temporarily replaced by heavy rain squalls coming from nimbus shreds flying past. The uniform and dark background which is formed by the cirrus veil remains unchanged during the time of the bad weather; it becomes occasionally visible through the gaps between the low nimbi which fly along at a frantic speed. In the central calm also this veil appears more or less dense.

The gradation in which the various phases follow each other serves as a useful indication as to the position, extent, and distance of the cyclone.

During the first stages of development the cirrus veil is always more developed toward the side of the center; during the later stages the masses of clouds are always more dense on that side.

If the cirrus veil incloses or covers the cirro-strati, and the phases follow each other slowly with a decided fall of the barometer at the same time, this is a sign that the cyclone has a great magnitude, and that it is still very far off at the time when the cirrus veil appears. The contrary happens in a cyclone of small diameter.

Solar and lunar halos.[1]—Halos round the sun and moon usually accompany the cirrus veil; parhelia, mock-moons, and aureoles round the planets and stars of the first magnitude are less frequently observed. Every sailor ought to remember that the halos which follow after fine weather are as a rule indications of great atmospheric changes; they are often closely followed by very bad weather.

With regard to the names of the halo phenomena referred to by Dr. Schipps as proper to be used in the observers' condensed descriptions, the following list, compiled from Mascart's Treatise, will be helpful:

"Corona," or "glory."—A circle of light or color surrounding the sun or moon or any other source of light, either celestial or terrestrial; the angular radius of such circles very rarely exceeds 5°; the largest that has yet been observed is the so-called Bishop's circle of about 15° radius, first described by Sereno Bishop, of Honolulu, in connection with the haze due to the eruption of Krakatoa, August 27, 1883.

"Antisolar coronas," or "antilunar coronas."—Similar small circles of light or bands of color surrounding the antisolar point and seen with especial beauty when, from a mountain top or a balloon, the observer's shadow is cast upon the clouds, and sometimes when it is simply cast upon a meadow covered with dew.

"Shadow beams," or "perspective beams," or "solar beams," or "beams of light and shade."—These beams, due to the shadows of clouds in the sky, or of mountains and terrestrial objects when the sun is below the horizon, appear to converge toward the solar and the antisolar points, and are widest apart in the region perpendicular to the line joining the sun with the observer. They are, in fact, parallel with each other, and the convergence is only an illusion of perspective.[2]

The peculiarities of all halos depend upon the size of the particles or drops of water, the uniformity in size and shape, the number of reflections within the drops, and the mutual distance of the drops or particles from each other. Ullao's white rainbow appears to be formed, according to Mascart, by the overlapping of bows formed by a mixture of drops of all sizes.

The second set of optical phenomena are due to the presence of crystals of ice of various forms, hexagonal prisms, flat plates, and hexagonal pyramids, either alone or in combination with drops of water. The optical phenomena due to these may be designated by the following among other names:

"Antisun," or "anthelion."—The bright spot or point directly opposite the sun, or directly in the line of the shadow of the observer's head.

"Halo of 22° radius" from the sun.

"Halo of 46° radius" from the sun.

"The tail of the halo;" a projection attached to the halo of 22°, and also to the halo of 46°.

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[1] See the letter of Mr. K. Schipps, "Anleitung und Einladung zur Beobachtung der Halophänomene," extract from "Jahreshefte für vaterl. Naturkunde in Württ," 1897.

[2] See "Monthly Weather Review for July, 1897," p. 305.

On the route from Havana to Europe, taking into account the general atmospheric circulation of cyclones and the equatorial current, halos and the cirrus veil are, in general, indications of southeast, south, and southwest winds. These halos are to be looked upon with special suspicion in those seas during the months from July to November; the mariner must then be on his guard and carefully watch the barometer, the sky, and the sea, because then the enemy is generally not very far off.[1]

The halos are at first but slightly developed; during the second phase of the cirrus veil they are especially beautifully formed, but with the increase of the thickness of the veil they go back in their development, and finally disappear altogether. Later on, the direct rays of the sun are altogether cut off, the sun's disk is completely veiled and covered; only the place can then be recognized where the sun stands in the sky.

If the dry, fresh, and fine weather, with a high barometer, which is due to the influence of the anticyclone, refreshes our senses, increases our energy, and cheers up our spirits, the opposite conditions exercise a still more marked but depressing influence upon body and mind, and find a fitting expression in the dark, leaden-hued sky, the oppressive and damp heat, and the low barometer which are the companions of the hurricane.

The change of weather which is effected by the approach of the hurricane makes itself felt in so notable a way that we can predict bad weather by the discomfort, the heaviness of the limbs and the general indisposition, even without consulting any instruments. This phase is well known to everybody living on the Antilles. It is a general complaint on such occasions that the weather is oppressive; and in fact, one does feel heavy, all energy is gone, the perspiration is copious, the heat annoying and weakening, and the direct rays of the sun are simply unbearable.

Several factors contribute to this general indisposition due to atmospheric influence. Such are: The considerable diminution of pressure; the increased temperature accompanied by greater humidity; the concentration of the solar rays due to refraction in the cirrus veil; the complete absence of breezes or else their modifications during the hours of greatest heat; and finally, to complete the picture, the very aspect of the sky, which is dreary and melancholy.

The diminution of pressure produces a feeling of weariness and molestation, due to the fact that the internal organs are not under the accustomed equilibrium; the respiration becomes to a certain degree labored on account of the relative tenuity of the air. The excessive heat and dampness contribute on the one hand to effect an abundant perspiration, while on the other they cause the evaporation of the sweat to proceed very slowly; wherefore the cooling effect of this evaporation is nearly nil—at any rate insignificant. The perspiration under such circumstances debilitates and irritates but does not cool, the heat itself becomes, so to say, sticky. Quite the contrary of this happens on days with ordinary breezes, on which the cutaneous transpiration and the cooling produced by its constant and rapid evaporation ease us considerably and alleviate the heat, so that it does not affect us so terribly.

Electric phenomena.—As to the typhoon indications which may be furnished by electric manifestations, we merely reproduce what, on another occasion, we have written on this subject when discussing a *baguio filipino*—that is to say, a cyclone of the Philippines, strictly so called.[2] This typhoon first crossed the Visayas on May 10 and 11, 1896, recurved in the China Sea not far from Manila and, recrossing on the 18th of the same month, traversed the northwestern part of Luzon.

It is known that there is a great tendency toward the development of electric phenomena on the borders of the body of the cyclone, which is the cause of heavy thunderstorms. This typhoon offers us an excellent proof of this. On the 8th thunderstorms were noticed all over Luzon except the corner, which began to be invaded by the vast storm area. As the typhoon advanced upon the Archipelago the region of thunderstorms was reduced, so that on the 9th they were very frequent in all parts of the island except in the second quadrant from Manila, in which not a single thunderstorm was observed. On the 10th the zone of the electric disturbances was confined exclusively to the quadrants to the north of Manila, thus proving that the signalized barometric slope was of cyclonic origin. From these and analogous facts we may derive a simple and at times useful rule for approximately determining the whereabouts of a cyclone. If in a given locality the barometer has a tendency to fall and after careful observation one well-defined region is found to be entirely free from every indication of a thunderstorm—that is, of thunder clouds or visible displays of atmospheric electricity—or if there are indeed local thunderstorms toward said region, but not coming from it, there will be reason to suspect that toward that point lies the body of the storm, especially if the prevailing winds or, better still, the resultants confirm it according to the general laws of cyclonic circulation.

For the better understanding of this note it is necessary to remember that real thunderstorms (we do not speak of every simple manifestation of electricity) are rarely observed within the interior of the cyclonic storm, and hardly ever in the vortical region, or, to express ourselves more exactly, in the border line between the relative and absolute calm. An explanation of their exceptional appearance in this zone is given in the Revista Meteorol. for the month of June, 1894, page 165.

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[1] Fr. Viñes, "Apuntes, etc."

[2] See classification of cyclones, Part I, Chapter X, pp. 89 ff.

What we have said concerning the baguios has also during many years repeatedly been observed by Fr. Viñes during cyclones of the Antilles. Speaking of these he says:[1]

> This—that is, the absence of electric discharges within the cyclone—is a phenomenon so constantly observed that whenever during a tempest the rolling of thunder is heard or flashes of lightning are perceived this is considered as a favorable sign indicating the speedy disappearance of the storm.[2] Especially among the country folks this opinion is general and deeply rooted. The crashing of thunder and the crowing of the cock are here the barometer of the farmer during cyclones, a barometer which, as he affirms, never deceives him. As long as the rooster does not crow, nor is there heard any peal of thunder, the storm will continue to rage in full force. But as soon as the lively crowing of the cock or the pealing of the thunder reaches his ear, the tempest, to his conviction, is about to pass away.

The scintillation of the stars and transparency of the air.—Some authors enumerate also the scintillation of the stars among the indirect premonitory signs of typhoons; especially Montigny has tried hard to bring this phenomena into connection with meteorology. We find it likewise mentioned by Reid, Redfield, and others of the older authors. Should there be a connection between the scintillation of the stars and the vertical thermic gradient, this must be the same which exists between the cyclone and this same thermic gradient. Of this gradient, however, we know as yet very little, except that it is exceedingly difficult of observation. Moreover, we frequently observe the scintillation of the stars in the Tropics during dry weather and on days when the air is exceptionally transparent—that is to say, when the cyclones which pass in the Tropics through higher latitudes are rare. From these remarks the reader may judge what value is to be attached to the scintillation of the stars and the transparency of the air as indirect precursory signs of a cyclone.

The coloration of the clouds.—The coloration of the clouds, as it appears especially at the times of sunrise and sunset, is also often counted among the indications of cyclones. The cirrus veil, already discussed, sifts the light to a great extent, letting principally the red rays pass, and absorbing the others almost entirely, whenever the oblique rays of the sun have to penetrate through a large part of the atmosphere. This selective absorption of the light at sunrise and sunset effects—as long as the cirrus veil is present—a characteristic coloring of the sky, which some describe as "copper-red," while others call it "brick-red." With the gradual disappearance of the light the red becomes darker, taking on a violet tint, which occasionally continues after sunset. Should there be solitary cumuli, or cumulo-nimbi near the horizon, vividly glittering and beaming reflections of a preponderating violet tinge are to be seen on the red tops of these clouds. These colorations, which many authors describe in such poetic terms, appear, it is true, usually just before hurricanes burst forth; but it is not less true that they are likewise observed at times of simple atmospheric disturbances, or simple thunderstorms. They appear most frequently when there are two distinct disturbances on the horizon. The reason of this is that the false cirri take the place of the cirrus-veil, decomposing the light in the same way, and so give rise to all the various tints and colors, just like the true cyclonic cirrus veil. We have also noticed similar colorings when the sky was covered with true cirri, but not of cyclonic origin. We must, therefore, place these colorings in the same category with the other indications which we have discussed in this chapter.

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[1] "Apuntes Sobre los Huracanes de las Antillas," p. 190.

[2] Fr. Viñes maintains that whenever an electric discharge is observed within the interior part of a cyclone it is much more likely to be in the rear of the vortex than in front of it. The general conviction of the people which he speaks of seems to bear out this statement.

CHAPTER X. MICROSEISMIC MOVEMENTS AS AN INDIRECT PRECURSORY SIGNAL OF A CYCLONE.

On writing of the cyclones of 1894 we said:[1]

> We call attention to the intimate relation there appears to be between the resistance offered to the cyclonic winds by mountain ranges and the microseismic movements.
>
> A notable fact points out this relation. In the adjoined map of Luzon (Pl. XLVII *a*) the track of a cyclone has been divided into parts corresponding to the movement of the storm for every two hours. In the lower part, the curve A represents the velocity of the wind in meters per second; the upper curve B representing the microseismic movements observed on the Bertelli tromometer; each division represents an angle of 14".
>
> Examining the curves we note the following important facts:
>
> (1) The greater or less amplitude of the oscillations does not depend on the greater or less force of the wind in the locality; for in the cyclone the maximum oscillation of the tromometer was observed at 12.30 a. m., whereas the maximum velocity and force of the wind was not observed till nine hours later.
>
> (2) The mean value of the microseismic oscillations is incomparably greater while a cyclone is crossing land than while it is crossing the sea.
>
> (3) The greatest oscillations are observed when the cyclone is passing the great mountain ranges.
>
> From these facts it would appear that the enormous resistance offered by the mountains to the cyclonic winds which blow, at the approach of a cyclone, from the fourth quadrant, almost perpendicular to the range of mountains in the district of Principe, causes a huge mass of the earth's crust to vibrate, and the vibrations thus caused being transmitted to a distance are made perceptible by the great sensitiveness of the Bertelli tromometer. The effect of the wind blowing against the mountains of Zambales is also perceptible in the same instrument.

In the tables published from time to time in the monthly bulletin of the Observatory may be seen numerous examples of this relation between the microseismic movements and the course of a cyclone.

The analysis of the microseismic movements during the passage of two typical cyclones offers a special interest. These are the cyclones of May 8–14, 1895, and that of May 9–18, 1896. The observations are given in the Tables A and B.

(1) The tromometer in both cases began to show the oscillations as soon as the cyclone made its appearance in the Archipelago—that is, on the morning of May 9, 1895, and at noon of May 10, 1896.

(2) The nearer the center was to Manila the greater were the oscillations of the tromometer, quite independently, however, of the wind in the locality, as for example during the evening and night of May 10, 1895, when the wind did not attain the velocity of 11 miles an hour.

(3) As in the former case the oscillation was greater when the center of the cyclone passed over the land than when it passed over the sea. These facts suffice of themselves to authorize us to say that "the microseismic movements can be used as an indirect precursory sign of a cyclone." This proposition can be proved empirically by the following tables, in which we compare the angular oscillation of the tromometer with the distance and position of the cyclonic vortex and the direction and force of the wind.

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[1] "Baguios ó Tifones de 1894." Manila, 1895, p. 79.

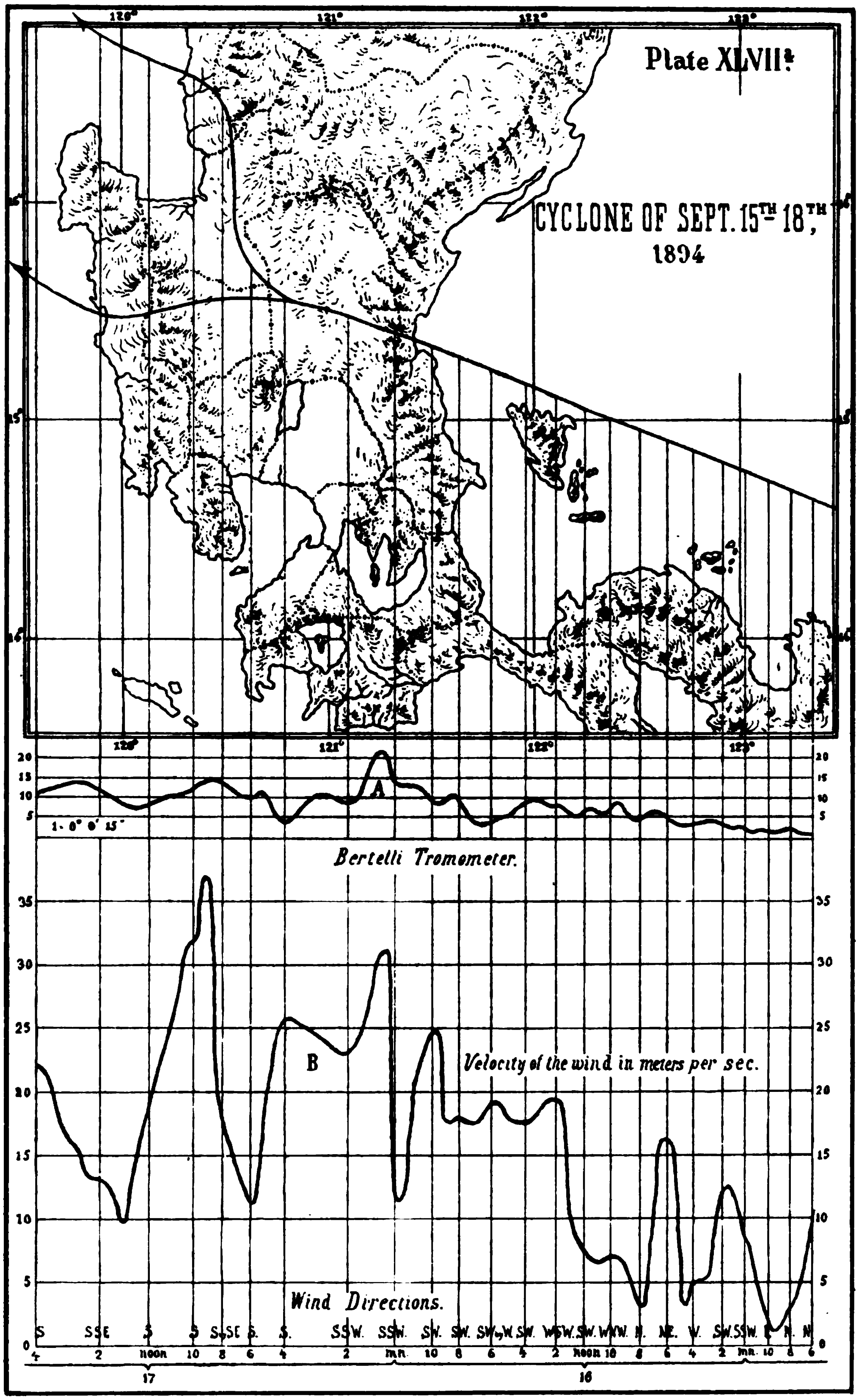
Plate XLVIIa
CYCLONE OF SEPT. 15TH-18TH, 1894
120°
121°
122°
123°
A
1. 0° 0' 15"
Bertelli Tromometer.
B
Velocity of the wind in meters per sec.
Wind Directions.
S SSE S S S.SE S. S. SSW. SSW. SW. SW. SW.W.SW. WSW.SW. WNW. N. NE. W. SW.SSW. E N. N
4 2 noon 10 8 6 4 2 mn. 10 8 6 4 2 noon 10 8 6 4 2 mn. 10 8 6
17
16
0
5
10
15
20
25
30
35

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The first two columns of Table A give the year, month, day, and hour of the observations; the third column, the mean oscillation of the tromometer during the hour; the fourth, the mean distance of the center in miles; the fifth, the direction of the wind; the sixth, the force of the wind in kilometers; the seventh, the maximum force of wind during the passage of the cyclone, in meters, per second; the eighth, the tromometrical oscillation at the moment of the maximum force of the wind and the maximum oscillation and the least distance of the center of the cyclone in miles, and the ninth, the position of the center relative to sea or land.

TABLE A.

Date of observation.		Mean angular value of the oscillations.	Mean distance of vortex.	Winds.		Maximum velocity of wind at Manila.[2]	Oscillation during maximum velocity and maximum oscillation.	Place of center.
Year, month, and day.	Hour.			Direction.	Velocity.[1]			
1894.		"	*Miles.*					
Sept. 15	2.00 p. m.	25	220	SW.	14	37	[3] 3' 3"	Sea.
Sept. 15	8.00 p. m.	60	130	N.	24.5			Sea.
Sept. 16	Noon	150	72	SW.	19			Sea.
Sept. 16	Midnight	300	55	SSW.	72.5			Land.
Sept. 17	9.00 a. m.	183	65	S.	64.5			Land.
Sept. 17	3.00 p. m.	170	110	SSE.	54.7			Sea.
Sept. 18	Noon	75	280	SSE.	27			Sea.
Sept. 18	10.00 p. m.	45	420	ESE.	9.5			Sea.
1895.								
May 10	9.00 a. m.	30	400	N.	11.5	17 (bis)	[4] 90 45	Sea.
May 11	3.00 p. m.	36	210	NNE.	8.5			Sea.
May 12	Midnight	60	215	ESE.	10.5			Sea.
May 15	Noon	45	270	SE.	29			Sea.
May 16	Noon	75	260	SE.	37			Sea.
May 17	11.00 a. m.	60	220	SSW.	54.5			Sea.
May 17	8.00 p. m.	90	225	WSW.	60.5			Land.
May 18	Noon	60	420	WSW.	7.5			Sea.
May 8	Noon	20	390	WSW.	16	16	[5] 1 0	Sea.
May 8	Midnight	105	280	SE.	2			Sea.
May 13	10.00 a. m.	105	70	SSW.	26			Land.
May 14	9.00 p. m.	50	420	WSW.	26.5			Sea.
May 15	Noon	50	500	SW.	32			Sea.
1896.								
July 27	8.00 a. m.	30	341	E.	44.3	15 (bis)	[6] 00 45	Sea.
July 27	1.00 p. m.	45	270	SW.	12.3			Sea.
July 27	Midnight	45	210	SW.	2.6			Sea.
July 28	6.00 a. m.	60	205	WSW.	39			Sea.
July 28	10.00 a. m.	82	215	WSW.	44			Land.
July 28	1.00 p. m.	75	230	SW.	31			Land.
July 28	8.00 p. m.	90	240	S. by SE.	15.5			Sea.
July 29	4.00 p. m.	60	460	W.	19			Sea.
Oct. 3	7.00 a. m.	30	325	NW.	7.5	20 (ter)	[7] 2 30	Sea.
Oct. 4	1.00 a. m.	185	162	WSW.	51.5			Sea.
Oct. 4	8.00 a. m.	204	155	W. by SW.	60.5			Land.
Oct. 4	2.00 p. m.	75	172	WSW.	54.5			Sea.
Oct. 5	5.00 a. m.	60	370	Calm.	6			Sea.
Oct. 5	11.00 p. m.	25	520	Calm.	1			Sea.
Oct. 8	5.00 a. m.	27	525	N.	13	20	[8] 00 45	Sea.
Oct. 9	1.00 a. m.	105	340	WNW.	45			Sea.
Oct. 9	8.00 a. m.	120	260	W.	43			Sea.
Oct. 9	3.00 p. m.	120	205	W. by SW.	51.5			Sea.
Oct. 10	11.00 a. m.	80	185	SW. by W.	29.5			Sea.
Oct. 11	Noon	75	330	SSW.	18			Sea.
Oct. 11	6.00 p. m.	45	405	SSW.	20			Sea.

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[1] Kilometers per hour.

[2] Meters per second.

[3] Maximum, 360"; minimum distance, 50 miles.

[4] Maximum, 105"; minimum distance, 200 miles.

[5] Maximum, 105"; minimum distance, 60 miles.

[6] Maximum, 90"; minimum distance, 190 miles.

[7] Maximum, 198"; minimum distance, 150 miles.

[8] Maximum, 150"; minimum distance, 165 miles.

In Table B we compare the mean values of the distance of the center of the cyclone, the angular oscillation, and the force of the wind in the locality.

TABLE B.

Distance of the center from Manila.	Angular oscillation.	Velocity of the wind.[1]	Number of cases.
Miles.	"		
522	26	7	2
432	48	19.7	7
349	51	22.5	6
234	77	28.8	17
152	131	45.8	6
65	184	45.5	4

[1] Kilometers per hour.

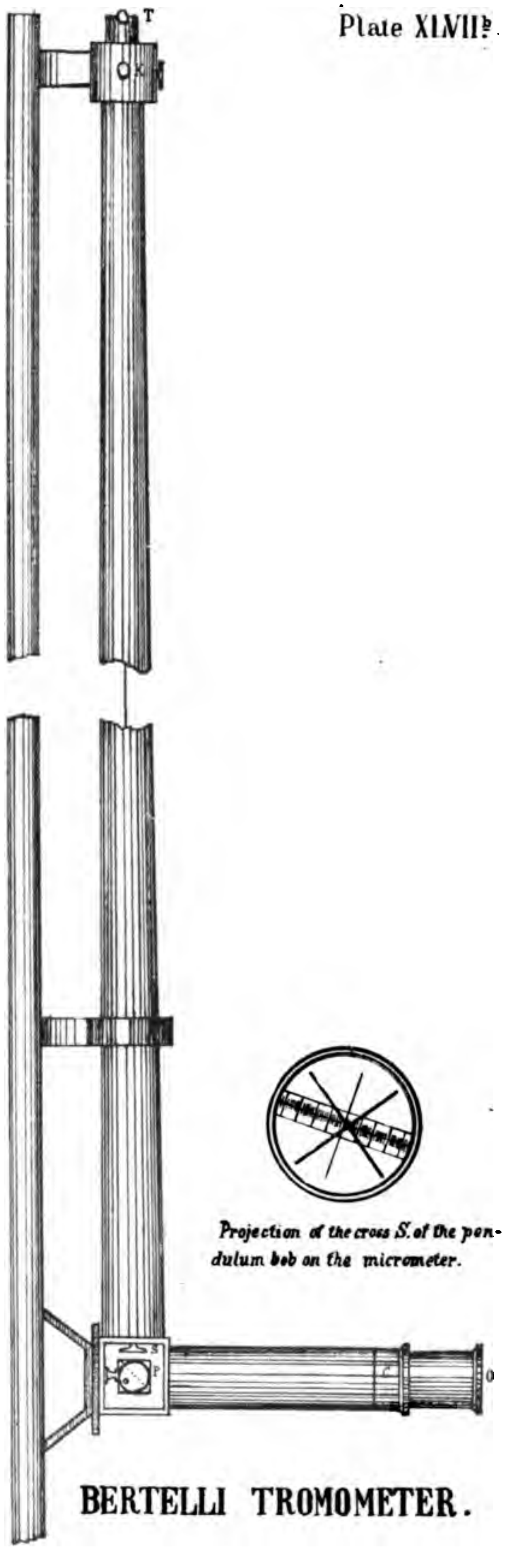
A careful examination of the tables leads to the following conclusions:

First. The tromometrical oscillations and the distance of the center of the cyclone vary inversely, but the proportion is not a mathematical one. It is sufficient to compare the columns 3, 4, and 7 of Table A and columns 1 and 2 of Table B to show this. The reason why these values are not strictly proportional may be attributed, first, to the difference of energy in different cyclones; second, to the position of the center, whether on land or on sea; third, to the state of the sea around Luzon which depends on the geographical position of the center.

Second. The force of the wind in the locality has a certain relation with the movements of the tromometer, but it can not be considered as their cause. The coexistence of the microseismic oscillations and of the wind may be shown by a comparison of the columns 2 and 3 of Table B and of columns 7 and 8 of Table A. This simultaneity can be easily understood since the cyclonic movement is the common cause, both of the perturbation of the air and the force of the wind as well as the movements of the earth or of the microseismic oscillations. In columns 3 and 5 we see remarkable microseismic movements without local wind, and we know that for the same local wind we have different microseismic movements. It would appear that the direction of the wind had a slight influence on the oscillations of the tromometer. This is doubtless because the direction of the wind depends upon the orientation of the center of the cyclone.

Third. The gradual perturbation of the tromometer constitutes an indirect sign of the existence and approach of a cyclone; but a sign which has only a relative scientific value depending upon the experience of the microseismic movements proper to each locality and also on the frequency of microseismic movements produced by endogenous causes. We notice three important points in this conclusion. The first is that the miscroseismic oscillation is an indirect sign of a cyclone. The second, that the scientific value of this sign is purely relative and depends upon the experimental knowledge of the movements in each locality; for the geographical position, the topographical, and even the geological constitution of the soil play a great part in facilitating or hindering the transmission of the mechanical movements produced by cyclonic forces. All these factors have to be taken into account and their influence on microseismic movements determined by experiment. Finally, the scientific value of these microseismic movements as a sign of a cyclone depends upon the frequency of the movements produced by endogenous causes. This is the principal cause why the microseismic movements can not have an absolute value. An isolated observer has no means at hand to know whether the oscillations of the tromometer are due to external causes or to the endogenous movements; he could not, therefore, form a definite judgment without the help of other signs. It is necessary to point out, however, that as the microseismic movements are different in different parts of the world, the value of this sign will be more or less advantageous in the different localities. It seems good to add here that the effect of the endogenous causes on the tromometer seem to be sharper and more sudden, while those caused by cyclonic forces have a more lasting and persistent character. The examination of the graphic traces for May shows this

Plate XLVII^{b}.



Projection of the cross S. of the pendulum bob on the micrometer.

BERTELLI TROMOMETER.

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quite clearly. The sudden oscillation which was seen about midnight of the 16th was the effect of an earthquake which took place in the Province of Batangas, in Mindoro, Marinduque, and in the north of the Island of Mindanao. The experience gained from the effect of cyclones on the microseismic apparatus in the Manila Observatory could help us in choosing the most suitable places for the installation of tromometers as an apparatus for giving indications of the existence and approach of tropical cyclones. If tromometers were installed in the following places great good would doubtless result from the meteorological point of view:

Havana, in the Antilles; San Juan, in the Island of Puerto Rico; the islands more to the east of the Gulf of Mexico; the ports of the United States on the Atlantic coast, especially that of Florida; in the ports of the Gulf of Mexico; and in the ports of China and the south of Japan.

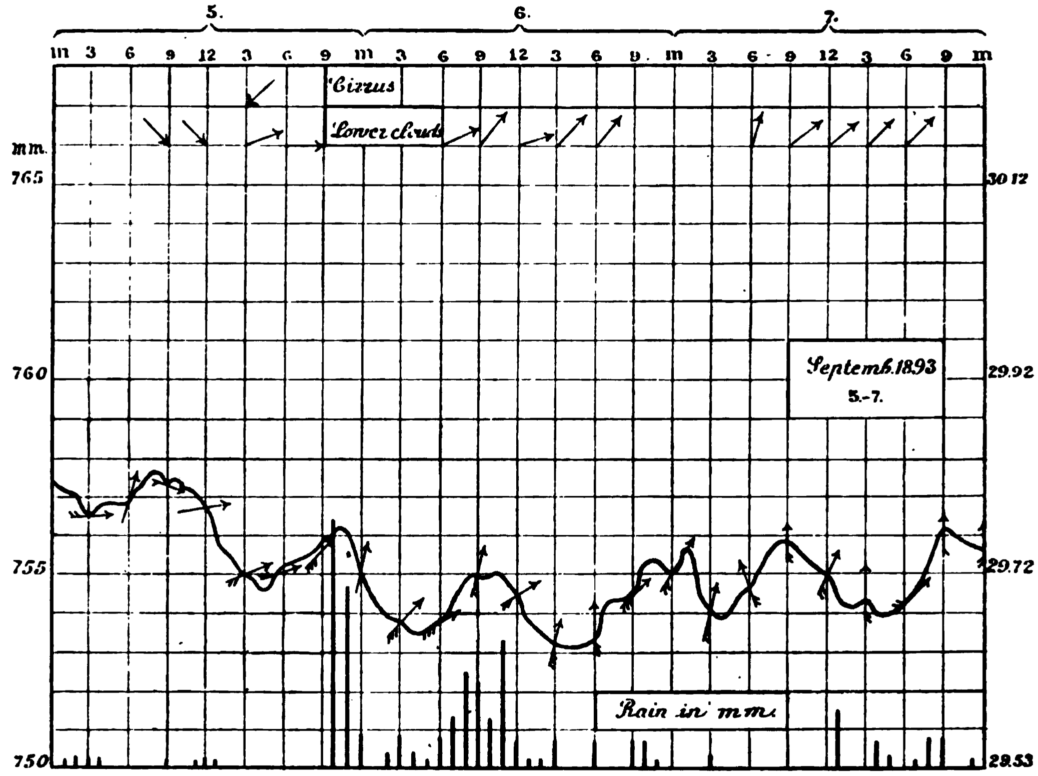
Description of the Bertelli tromometer (Pl. XLVII^b).—We add here a short description of the Bertelli tromometer as used in the Manila Observatory. It consists of a pendulum which is composed of a small weight and a fine copper wire 1.5 meters long, suspended by means of a system of adjustable screws TK, and the whole inclosed in a metal tube to exclude currents of air. The weight ends in a small disc S, upon which is marked a small cross which is reflected by means of a prism P into the eyepiece of the telescope O. To illuminate the cross on the pendulum bob the box in which the reflecting prism is placed has glass faces, and light is reflected on to the surface of the bob by means of a bright metal plate. With this arrangement the direction and amount of movement can be seen at once. The direction is easily obtained by means of the ring C placed on the tube of the telescope. The points of the compass are marked on this ring so that noticing the direction in which the pendulum is moving and then looking at the ring we see at once the direction of the oscillation.

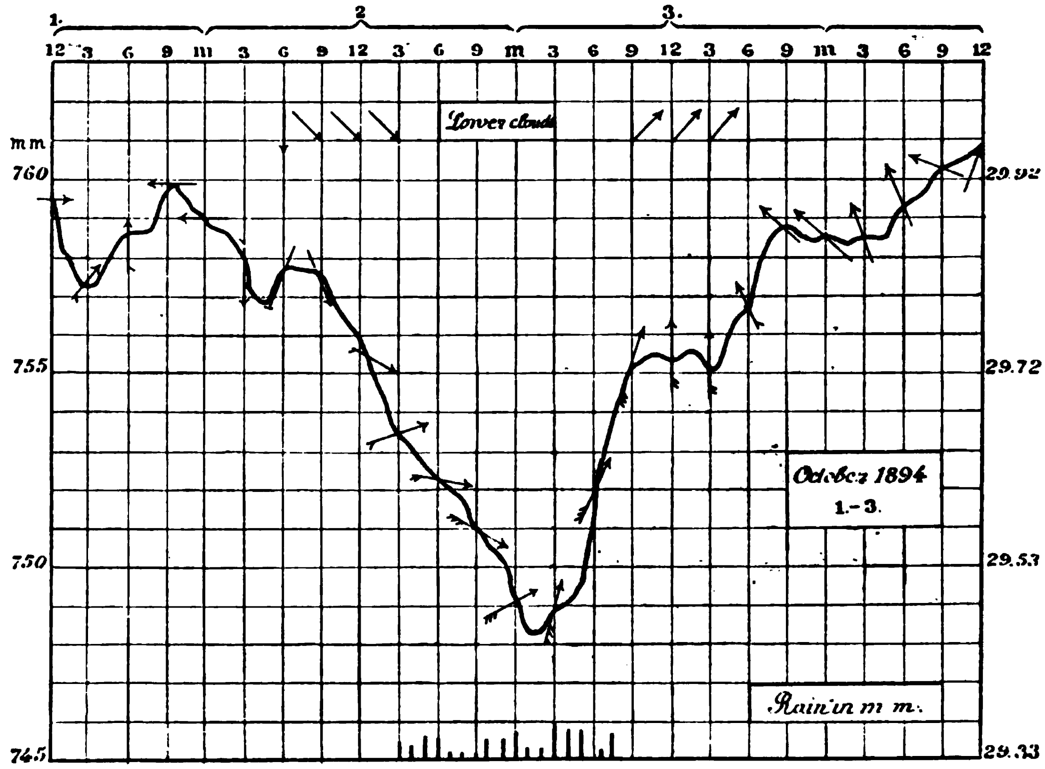
To determine the amplitude of the oscillation the telescope carries a micrometer which reads to tenths of a millimeter, each one of which is equivalent to 15″ of arc. Observations with this instrument are made every hour of the day and night, and have been continued since 1884. Besides the Bertelli tromometer there is in the Observatory the Cecchi microseismograph and the Vicentini microseismograph which, being self-registering, have an advantage over the Bertelli tromometer.

What has been said is sufficient to give some idea of the principal indirect signs, and we now pass on to give some practical applications of what we have written in Parts I and II. We will also discuss some of the exceptions, or anomalous cases, which occasionally are observed, that the observer may be guided in deducing practical warnings from the anomalous cases, as well as from the typical, or normal ones.

PART III. TYPICAL CYCLONES.

Plate XLVIII.





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PART III. TYPICAL CYCLONES.

Introduction.—In Part III we do not undertake a complete discussion of determined typhoons, but a special study of the first symptoms which are generally felt in a locality at the approach of one of these storms and the indications which follow as to the position of the vortex, the intensity and direction of the storm, that we may in a certain measure foresee its effects. We then follow the trajectory till the storm has ceased to exert any influence on the locality; but we do not intend here to determine the origin of the storm or to trace out the trajectory throughout its entire length, because it is only our intention to guide the particular observer in the use of the data he has at hand that from them he may judge for himself whether the circumstances and nature of the storm are analogous to the example and what will be the probable influence it will exert upon the locality.

We rely principally on the influence which typhoons have exercised on Manila, where, on account of the Observatory, we have the most numerous and correct data. From these we can deduce what will be the effects on other places in equal or analogous circumstances. Since the whole of this study is based on experience, we treat at greater length several typical cyclones which have passed Manila at different distances and which have reached their minimum distance from the city from different positions. We therefore treat, first, of a cyclone which passed far to the north of Manila, at a minimum distance of 250 miles, and then of the general characters of typhoons which pass by the north of any place; second, of a cyclone which passed by the north close to Manila, and of the general character of typhoons which pass close or very close to a place by the north, and so on with the different positions at which cyclones may pass a place.

CHAPTER I. THE CYCLONE OF SEPTEMBER 5 TO 7, 1893.

PLATE XLVIII, UPPER HALF.

Classification.—This cyclone belongs to the typhoons of Luzon and China, sixth type. Its mean velocity of translation while crossing Luzon was 9.6 miles an hour and the least distance of the vortex from Manila was 250 miles. The inclination of the trajectory near the meridian of Manila was W. 28° N., while in the China Sea it was inclined more to the north, which was owing to a cause of which we shall speak at the end of the study.

First Indications.—The slow fall of the barometer from the 4th and the fine rain which became more copious on the morning of the 5th, convergence of cirri to northeast by east at first, and somewhat later to northeast, and specially the permanence of the west-southwest winds from the morning of the 5th, were all unfailing indications that a cyclonic center would cross the meridian of Manila at a distance to the north. This was understood, and the director of the Observatory announced to the captain of the port at 2.57 p. m. of the 5th the following: "You may give notice that there is probably a typhoon in the northern provinces."

Observations during the typhoon.—The wind gradually increased in force during the 5th and 6th and all the former indications were becoming more marked. We give a detailed list of the observations of the phenomena which preceded and accompanied the passage of the great typhoon.

OBSERVATIONS DURING THE CYCLONE OF SEPTEMBER 5 TO 7, 1893.

Date.		Barometer.	Thermometer (Celsius).	Relative humidity.	Wind.		Clouds.					Rain.	Remarks.
Day.	Hour.				Direction.	Force, 0–12.	Amount, 0–10.	Higher.		Lower.			
								Form.	Direction.	Form.	Direction.		
			°	*Per ct.*								*Mm.*	
Sept. 5	6.00 a.m.	756.94	23.9	96.0	SSW.	1	10	----	----	N.	WSW.	----	Drizzling rain.
	7.00 a.m.	57.11	24.3	92.0	E.	1	10	----	----	Cu.-N.	WSW.	0.1	Horizon dark with rain.
	8.00 a.m.	57.40	24.9	96.0	E.	1	10	----	----	N.	WSW.	.1	Local drizzle.
	9.00 a.m.	57.81	26.5	98.0	WNW.	3	10	----	----	Cu.-N.	SW., NW.	----	Squalls in second and third quadrants.
	10.00 a.m.	57.39	25.9	88.5	W.	4	10	----	----	N.	NW. by W.	----	Commencement of wind and rain squalls.
	11.00 a.m.	57.01	26.1	89.0	W.	3	8	----	----	N.	NW.	.6	Squalls in second and third quadrants.
	Noon	56.71	25.7	91.0	WSW.	3	10	----	----	N.	NW.	.9	Squally.
	1.00 p.m.	55.71	28.3	81.0	WSW.	3	8	Ci.-Cu.	----	Cu.-N.	WSW.	.1	Storm cloud all around the horizon.
	2.00 p.m.	55.25	27.7	81.5	SW.	6	9	Ci.-Cu.	----	Cu.-N.	WSW.	----	
	3.00 p.m.	54.91	28.3	75.0	WSW.	5	8	Ci.-S.	NE.	Cu.	WSW.	----	Ci. convergent to NE. by E.?
	4.00 p.m.	54.45	27.4	80.0	WSW.	5	9	Ci.-Cu.	----	S.-Cu., N.	WSW.	----	Squalls in second quadrant; velocity of wind, 15 to 16 meters per second.
	5.00 p.m.	54.62	27.2	80.0	WSW.	6	9	Ci.-Cu.	----	S.-Cu.	WNW.	----	Gusts 16 to 17 meters per second.
	6.00 p.m.	55.04	27.2	81.0	WSW.	5	10	----	----	S.-Cu., N.	W.	----	Fine local rain begins.
	7.00 p.m.	55.24	27.4	81.0	WSW.	6	10	----	----	S.-Cu., N.	W.	----	Gusts 15 to 17 meters per second.
	8.00 p.m.	55.41	27.1	84.0	SW.	6	9	----	----	Cu.-N.	----	----	Gusts 16 to 18 meters per second.
	9.00 p.m.	55.46	26.8	83.0	SW.	5	10	----	----	Cu.-N.	----	----	Gusts 15 to 17 meters per second; drizzling.
	10.00 p.m.	56.01	26.6	86.0	SW.	4	10	----	----	Cu.-N.	----	36.2	Gusts 12 to 14 meters per second; rain.
	11.00 p.m.	55.85	26.1	86.0	W.	8	10	----	----	Cu.-N.	----	28.5	Local rain.
	Midnight	54.72	25.8	94.0	SSW.	7	10	----	----	Cu.-N.	----	5.2	Fine rain; gusts 21 to 23 meters per second.
Sept. 6	1.00 a.m.	54.17	25.9	93.0	SSW.	7	10	----	----	Cu.-N.	----	----	Fain rain; 1.10 a. m. rain; gusts 20 to 23 meters per-second.
	2.00 a.m.	53.78	25.6	96.0	SW.	6	10	----	----	Cu.-N.	----	.9	Fine rain; gusts 17 to 19 meters per second.
	3.00 a.m.	53.56	26.4	90.0	SW.	6	10	----	----	N.	----	4.0	Local rain.
	4.00 a.m.	53.58	26.1	90.0	SW.	7	10	----	----	Cu.-N.	----	1.3	Drizzling.
	5.00 a.m.	53.56	26.7	87.0	SW.	7	9	----	----	Cu.-N.	----	----	Drizzling; gusts 18 to 20 meters per second.
	6.00 a.m.	53.68	27.4	82.0	WSW.	6	10	----	----	N.	WSW.	.2	Raining.
	7.00 a.m.	54.42	24.8	97.0	SW.	5	10	----	----	N.	WSW.	6.5	Raining; 7.38 a. m., gusts from SW., 20 to 23 meters per second.
	8.00 a.m.	54.68	24.6	98.0	SW.	5	10	----	----	N.	SW., WSW.	13.4	Horizon limited by rain.
	9.00 a.m.	54.92	25.3	96.0	SW.	3	10	----	----	S.-Cu., N.	SW.	12.0	Slightly clearing in second quadrant, rest rain clouds.
	10.00 a.m.	54.73	24.7	99.0	SW.	3	10	----	----	Cu.-N.	SW. by W.	7.9	Relatively clear in SSW.; rain in rest.
	11.00 a.m.	54.88	24.4	99.0	WSW.	3	10	----	----	N.	WSW.	17.5	Rain.
	Noon	54.27	24.3	98.0	SW.	6	10	----	----	N.	WSW.	3.0	Do.
	1.00 p.m.	53.81	25.4	96.0	SW.	3	10	----	----	S.-Cu., N.	SW. by W.	.7	Do.
	2.00 p.m.	53.48	25.5	95.0	SSW.	6	10	----	----	N.	SW. by W.	.8	Fine rain.
	3.00 p.m.	53.09	25.6	87.0	SSW.	5	10	----	----	N	SW.	----	Do.

OBSERVATIONS DURING THE CYCLONE OF SEPTEMBER 5 TO 7, 1893—Continued.

Date.		Barometer.	Thermometer (Celsius).	Relative humidity.	Wind.		Clouds.					Rain.	Remarks.
								Higher.		Lower.			
Day.	Hour.				Direction.	Force, 0-12.	Amount, 0-10.	Form.	Direction.	Form.	Direction.		
			°	*Per ct.*								*Mm.*	
Sept. 6	4.00 p.m.	53.14	26.1	82.0	SSW.	4	10	--------	------	S.-Cu., N.	WSW.	0.1	Rain in all quadrants.
	5.00 p.m.	53.12	25.1	92.0	S.	5	10	--------	------	N.	SW. by W.	.3	Raining.
	6.00 p.m.	53.62	25.3	93.0	S.	5	10	--------	------	N.	SW.	1.9	Drizzling; 6.23 p. m., squalls of wind and rain from SW.; velocity, 22 meters per second; gusts of 27 meters per second maximum.
	7.00 p.m.	54.17	23.9	99.0	SSW.	4	10	--------	------	S.-Cu., N.	SW.	1.6	Squalls in all quadrants.
	8.00 p.m.	54.18	24.9	97.0	S. by SE.	3	10	--------	------	N.	------------	.5	Fine rain.
	9.00 p.m.	54.62	24.7	97.0	SW.	5	10	--------	------	N.	------------	.8	Squalls, 14 to 16 meters per second.
	10.00 p.m.	55.07	24.7	97.0	SW.	6	10	--------	------	N.	------------	3.5	Fine rain, followed by gusts 15 to 17 meters per second.
	11.00 p.m.	55.22	25.0	92.0	SSW.	4	9	--------	------	N.	------------	.1	Slightly clearing in zenith.
	Midnight	54.76	24.6	96.0[a]	SSW.	3	10	--------	------	N.	------------	------	Raining.

Clouds.—It is worth while to call attention to the constancy of the direction of the clouds and their veering, which was a manifest indication of the movement of the vortex. The direction of the lower clouds for September is from west-southwest to east-northeast. It could not be seen from this on the 5th at 6 a. m. that Manila would enter into zone A of a cyclone, when the barometer stood at 756.92 millimeters (29.80 inches); at 9 a. m., however, the lower clouds came already from the fourth quadrant (northwest), and the barometer showed a slight rise at that juncture.

Beginning with 9 a. m. on the 5th, and consequently thirty hours before the absolute minimum of the barometer, the clouds had continually a less convergence than the wind. This was the case, also, after the barometer had begun to rise afresh.

The clouds which prevailed during the time of the fall of the barometer were, of course, mostly nimbus and fracto-nimbus, which were occasionally so low that they were swept along by the lower currents, cumulo-nimbus and fracto-cumulus. These clouds covered the whole horizon to such an extent that the upper clouds could not be observed.

Rain.—In Manila on the 5th fine rain fell from 6 a. m. till nightfall. The squalls of wind and rain became more frequent after the wind had veered to southwest and blew from this point. At 10 p. m. on the 5th heavy rain was setting in; it kept on almost without any cessation whatever till 2 a. m. on the 7th. The greatest fall per hour was 36 millimeters (1.42 inches), with a southwest wind. The total rainfall of the two days amounted to 194.56 millimeters (7.66 inches).

Barometer.—During the passage of this typhoon Manila was exclusively in zone A. The daily movement of the barometer was, therefore, not obliterated; the amplitude and the hours for the maxima and minima were alone changed. The absolute minimum was registered at about 3 p. m. of the 6th, with south-southwest and south winds. The amplitude amounted to 2.33 millimeters (0.092 inches) on the 5th, and to only 1.42 millimeters (0.056 inches) on the 6th.

Important notice.—If, as was the case on this occasion and which frequently happens, the absolute minimum occurs at hours which are usual in the Tropics, it can not be determined whether the least distance of the center from the place has been reached at that precise epoch. The greatest uncertainty on this head prevails when the amount registered belongs to zone A. The probability that the least distance of the center has been reached (at the time of the minimum) is greater for the morning than for the afternoon, on account of the minimum of the morning being usually not so low as that of the afternoon.

Winds.—The wind veered from west to south; nor could the amount of rotation have been greater, since Manila was in zone A. The force of the wind varied. The squalls increased in force from 4 p. m. on the 5th, the heaviest (60.4 miles per hour) being observed at 6 p. m. on the 6th, and therefore not much later than the barometrical minimum.

The prevailing directions of the wind are those which are determined by the bearing of the center, supposing that the place lies within either zone A or zone B. The directions of the wind which are of a short duration only, such as come on during heavy squalls, and especially those which deviate from the preceding and subsequent ones, are here out of the question. The directions of the wind given in the table are those which were noticed precisely at the respective hours.

The further progress of the cyclone.—We find a description of the further progress of the typhoon in the Revista Meteorológica for September, 1893, in which is also mentioned an occurrence which shows that the storm warnings from Manila are of very great importance to the colony of Hongkong:

> On the 5th there were indications of a new depression which was lying to the NE. of Manila and was advancing toward the WNW. The center passed through the Channel of Balingtan, reached the China Sea, and then took a somewhat northerly direction. This small trend to the N. was noticed at Manila on the 6th, and reported to Hongkong: "Typhoon in the China Sea; direction WNW. if [si] it does not recurve more to the north." And to the press of Manila:
>
> "Barometers still low, but with a tendency to rise; the typhoon appears to be entering the China Sea in the direction WNW.; although it is probable that it will recurve more to the N."
>
> Owing to the carelessness of the telegraph clerk the telegram to Hongkong was mutilated, the word *si* (if) being changed into *y* (and), so that the telegram read: "Baguio en el mar de China; dirección ONO. *y* no recurva más al N." (Typhoon in the China Sea; direction WNW., and it will not recurve more to the N.) This change of a single word was fatal for the English colony, since it being taken for granted that the storm would not recurve more to the north, preparations were made for weathering it on the south, but suddenly on the night of the 8th the wind began to blow from northwest and west, and again on the morning of the 9th with extraordinary violence from the southwest; the cyclone had come very near the colony in the north The surprise was great and the damage done in the harbor and the city greater still.
>
> The colonial press issued a very severe criticism on the Observatory in Hongkong, saying that it had not noticed the recurving of the typhoon early enough, although Manila had notified this fact three days before the arrival of the storm, when it just commenced to make its influence felt in Hongkong. Others again accused the Observatory of Manila that it had announced that the typhoon was not further turning to the north. The Spanish consul in Hongkong explained the matter by quoting the newspapers from the Philippines, and a message which was sent by the telegraph office confirmed the fact that the telegram of the 6th had been mutilated.

THE CHARACTERISTIC QUALITIES OF CYCLONES WHICH PASS FAR TO THE NORTH OF A PLACE.

Remarks.—(1) When describing the general qualities in the case we do not take into consideration, generally speaking, the local topographic influences which may modify these phenomena, to a greater or less degree, but we propose from time to time to refer to them.

(2) We wish to remind the reader that by the word "far" we imply a distance of from 120 to 500 miles. The influence of cyclones will very often make itself felt at still greater distances. The typhoons which cross Luzon extend their influence not only as far as the Visayas but even to the south of Mindanao. The influence is then, however, not so great as to indicate danger for those regions; the progress of the phenomena is likewise not sufficiently regular to enable us to derive from them important rules for practical purposes.

(3) From the chart of the tracks it will be seen that during certain seasons some regions are not exposed to the dangerous influence of cyclones. This is the case in the months of the first group with the northern part of the Archipelago and the east coast of China, which are then not affected by the cyclones which pass over the south. The reverse takes place in the

months of the third group; the typhoons pass over the north of the Archipelago, while the south remains relatively free from their influence.

This being premised, let us now pass on to discuss briefly the general qualities of a cyclone which passes far to the north of a place, and also the way in which the storm usually shows itself at sea.

Clouds.—The cirri are usually the first indications of an atmospheric disturbance. But as it is difficult, especially at sea, to distinguish the true cirri from the false, which may be present in great numbers in the outer regions of the body of a cyclone, these indications are not decisive. We must wait for the appearance of other less doubtful symptoms, such as, for instance, the direction of the intermediate, and especially of the lower, clouds. If we notice that the intermediate clouds come from a northerly direction, but the lower from a point of the fourth quadrant, with an inclination to veer to the west, and the barometer shows a fall, even if but a slow one, we may be certain that there is a cyclonic center lying between east and northeast of the observer. If with this prognostic is associated the orientation or the convergence of the cirri towards this direction, all doubt may be set aside, especially if the given direction of the intermediate and lower clouds is maintained for a few hours; for there is no season in which the normal direction of the intermediate and lower clouds is that of the fourth quadrant. If the lower clouds, and correspondingly the intermediate ones, veer round to west, or even to the third quadrant, without the barometer falling considerably, the center will pass far to the north and the place will not leave the zone A. At sea we have above all to watch the direction of the hurricane swell.

Rain.—The rainfall is usually very heavy in a typhoon which passes in the north. It frequently happens in the Archipelago that the rain region extends considerably over the quadrant of the cyclone's left side. Such cases have occurred in the Visayas when centers passed over the north of Luzon, even when they crossed the channels of Baschi and Balingtan, as happened at the end of June and at the beginning and end of July, 1897. If the cyclone should remain stationary, or should be advancing but slowly, the rain will last for several days. The rain squalls are under such circumstances usually more frequent and copious in the third quadrant of the cyclone, and therefore at a time when the barometer commences to rise, or is rising already.

Barometer.—The fall of the barometer is slow as long as the place lies in zone A. The daily oscillation does not disappear; it is only the hours for the maximum and minimum and the amplitude which change. The best sign that a cyclone is passing at a distance is the drift of the lower clouds from the third quadrant (southern quadrant) without there being a great fall of the barometer.

Winds.—The direction of the wind usually changes to the third quadrant before that of the clouds if a cyclone is passing far in the north. The wind comes, therefore, steadily from this direction before the clouds, although rain squalls and other causes may for a short time be able to produce small changes. The force of the wind is very variable and intermittent; it does not always correspond to the movement of the barometer. Should the distance of the center be more than 250 miles the intervals between the rain and wind squalls are usually very long; so there occur longer pauses. Experience teaches that the wind and rain squalls are more frequent from midnight to daybreak, about noon, and toward evening, there being a noticeable increase in them when the center is about to recede.

CHAPTER II. THE CYCLONE OF OCTOBER 1 TO 3, 1894.

PLATE XLVIII, LOWER HALF.

Classification.—The cyclone belongs to the class of those of Luzon and China, sixth type. The mean velocity when crossing Luzon was 7.9 nautical miles per hour. Least distance from Manila, 80 miles. Direction of the track when crossing the Archipelago, W. 25° N.[1]

First indications.—On October 1 at noon, thirty-nine hours before the cyclone crossed the meridian of Manila, notwithstanding the high altitude of the sun, a plain convergence of cirri was noticed in the east, which led one to suspect the existence of an atmospheric disturbance. This was at the same time at which, according to a Hongkong telegram, the typhoon which had crossed the Archipelago on September 28 was recurving in the north of the Gulf of Tonkin. The barometer stood above its normal level. From 1 to 3 p. m. dark clouds and rain prevailed in the easterly direction, and also thunderstorms and electrical phenomena, which occur frequently in the outermost portion of a cyclone, were not wanting.

Observations during the typhoon.—About midnight on the 1st the barometer, although still high, was 2 millimeters (0.079 inch) lower than at the same hour of the preceding day. At 1 a. m. the north wind, which was accompanied by drizzle and rain squalls, began to freshen up; everything pointed to the conclusion that Manila would soon be in zone A of a new typhoon.

OBSERVATIONS DURING THE CYCLONE OF OCTOBER 1 TO 3, 1894.

Date.		Barometer.	Thermometer (Celsius).	Relative humidity.	Wind.		Lower clouds.			Rain.	Remarks.
Day.	Hour.				Direction.	Force, 1-12	Amount, 1-10	Form.	Direction.		
			°	*Per ct.*						*Mm.*	
Oct. 2	2.00 a. m.	758.45	24.2	97.0	N.	1	------	------	------	------	
	3.00 a. m.	58.20	24.2	95.0	N.	2	8	Cu.-N.	------	------	Light local rain.
	4.00 a. m.	56.92	23.9	98.0	NNW.	1	7	S.-Cu., N.	------	------	
	5.00 a. m.	57.09	23.9	99.0	N.	1	9	S.-Cu., N.	------	------	
	6.00 a. m.	57.50	23.8	100	NNE.	1	10	S.-Cu., N.	N.	------	
	7.00 a. m.	57.59	24.4	96.0	NNW.	2	9	S.-Cu., N.	NW.	------	Fog around horizon.
	8.00 a. m.	57.70	25.3	92.0	N.	2	10	S.-Cu., N.	NW.	------	
	9.00 a. m.	57.17	26.1	88.0	NNW.	2	9	S.-Cu., N.	NW.	------	
	10.00 a. m.	57.20	26.5	87.0	NNW.	2	9	S.-Cu., N.	NW.	------	
	11.00 a. m.	56.64	28.2	81.0	WNW.	3	8	S.-Cu., N.	NW.	------	
	Noon	55.77	28.9	76.0	WNW.	2	7	S.-Cu., N.	NW.	------	The S.-Cu. from NNE. are normal.
	1.00 p. m.	55.31	28.8	75.0	W.	2	9	S.-Cu., N.	NW.	------	
	2.00 p. m.	54.61	28.6	78.0	W.	2	10	S.-Cu., N.	NW.	------	Fine local rain; heavy rain clouds in first quadrant.
	3.00 p. m.	53.55	28.1	82.0	W. by SW.	3	10	S.-Cu., N.	NW.	1.8	Drizzle; rain in first quadrant; 3.10 p. m. rain and wind squalls from WSW.
	4.00 p. m.	53.46	27.6	84.0	WNW.	3	10	S.-Cu., N.	------	1.4	Gusts 13.5 meters per second; fine rain; 4.15 rain and wind squalls.
	5.00 p. m.	52.62	27.1	85.0	WNW.	4	10	N.	W.	2.8	Rain and wind squalls; gusts 10 meters per second, later 18 to 19 meters per second.
	6.00 p. m.	52.25	26.7	93.0	W. by NW.	6	10	N.	------	2.7	Gusts 22 meters per second.
	7.00 p. m.	51.78	26.8	84.0	W.	6	10	N.	------	0.6	Gusts 16 to 17 meters per second; rain: 7.30 p. m. gusts 19 meters per second.
	8.00 p. m.	51.52	26.9	84.0	WNW.	5	10	N.	------	0.4	Gusts 15 to 16 meters per second.
	9.00 p. m.	51.08	26.8	84.0	WNW.	6	10	N.	------	0.2	Gusts 16 to 19 meters per second; light rain.
	10.00 p. m.	50.90	26.5	86.0	W.	6	10	N.	------	3.0	Gusts 18 to 20 meters per second; rain.
	11.00 p. m.	50.37	26.5	86.0	W.	7	10	N.	------	3.1	Do.
	Midnight	49.08	26.5	86.0	WSW.	7	10	N.	------	1.9	Gusts 18 to 19 meters per second; rain.
Oct. 3	1.00 a. m.	48.42	25.9	88.5	WSW.	9	10	N.	------	1.6	Gusts 29 to 32 meters per second; wind oscillating between W. and SW.
	2.00 a. m.	48.30	25.3	89.0	WSW.	9	10	N.	------	1.5	Gusts 29 to 31 meters per second; at 2.35 even 37 meters per second.
	3.00 a. m.	48.60	24.3	98.0	SW.	10	10	N.	------	5.7	Gusts 34 to 35 meters per second.
	4.00 a. m.	49.67	23.6	98.0	SW.	9	10	N.	------	4.1	Gusts 30 to 31 meters per second.
	5.00 a. m.	51.10	22.8	99.0	SSW.	7	10	N.	------	4.0	Gusts 25 to 26 meters per second; at 5.10 gusts 31 to 34 meters per second.
	6.00 a. m.	52.62	24.7	92.0	SSW.	6	10	N.	------	1.0	Gusts 23 to 24 meters per second.
	7.00 a. m.	53.16	25.6	93.0	S.	5	10	N.	SW.	3.1	Light rain.
	8.00 a. m.	54.14	26.4	89.0	S. by SW.	5	10	Cu.-N.	SW.	------	Squally.
	9.00 a. m.	55.13	27.2	84.0	SSW.	5	10	Cu.-N.	SW.	------	
	10.00 a. m.	55.50	27.8	81.0	SSW.	4	10	Cu.-N.	SW.	------	Squally in all quadrants.
	11.00 a. m.	55.75	27.9	86.0	SSW.	3	10	Cu.-N.	SW.	------	
	Noon	55.28	29.6	80.0	S.	2	9	Cu.-N.	SW.	------	Rain in third and fourth quadrants.
	1.00 p. m.	55.07	29.4	79.0	S.	3	9	Cu.-N.	SW.	------	Do.
	2.00 p. m.	55.27	29.4	78.0	S.	4	8	Cu.-N.	SW.	------	Rain and wind squalls from S., 19 to 21 meters per second.
	3.00 p. m.	55.23	27.7	81.5	S.	4	10	Cu.-N.	SW.	------	Drizzle; rain in third and fourth quadrants; 3.15 squalls.

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[1] This typhoon has been fully discussed in "Baguios ó Tifones de 1894," pp. 102–109.

Fall of the barometer.—The slow fall of the barometer took place during the whole of the 1st. The distinct fall commenced at 9 p. m., and therefore twenty-nine hours before the lowest reading of the barometer and the greatest force of the wind, which were observed on the 3d at 3 a. m. The rapid fall, during which the daily variations became lost altogether, commenced on the 2d at 9 a. m.

Rain.—According to the observations given in the table, drizzle and rain was setting in at Manila at 2 p. m. on the 2d, in the first quadrant, the barometer showing 754 millimeters (29.69 inches). There were no thunderstorms, this being a proof that the rain belonged to a cyclone. Up to 10 p. m. on the 2d drizzle only prevailed, but during the rapid fall of the barometer, with southwest and south winds, the rainfall during the squalls became heavier and more copious. The total amount was 40.89 millimeters (1.61 inches). The largest quantity during one hour at the time of the greatest force of the wind from southwest was 5.69 millimeters (0.224 inch). All this corroborates what we have said about the influence of the geographical position of Manila and the distribution and amount of rain during cyclones.

Clouds.—In addition to our remarks concerning the cirri as being the first indications, we have to call attention to the remarkable constancy in the direction of the lower clouds as compared with the changes of the direction of the wind. From 11 a. m. on the 2d, fifteen hours before the barometrical minimum, the movement of the clouds was, generally speaking, less convergent, forming with the wind direction an average angle of 36°. After the center had crossed the meridian of Manila the angle was still 34°. This confirms what we have said in Part I, Chapter III.

Wind.—The force of the wind increased gradually from 4 a. m. on the 2d till 3 a. m. on the 3d, when it reached force 10, Beaufort scale; at this time the center had probably passed the meridian of Manila. The direction of the wind was not so steady as that of the clouds, but the prevailing directions indicated the place of the center correctly. The veering of the wind from north through west to south took place in accordance with the laws which govern the cyclonic circulation.

Barometer and barometric gradient.—The amplitude during the decisive fall of the mercury did not reach the amount of 1 millimeter (0.039 inch). During the rapid fall, however, the mercury descended at the rate of 0.55 millimeter (0.022 inch) average per hour. The mean gradient during the rapid fall was 1.05 millimeters (0.041 inch), but when the wind had reached the force 10 it rose to the extraordinary value of 1.65 millimeters (0.065 inch).

Further progress of the cyclone.—When the cyclone had reached the China Sea on the 3d, it did not change its direction at first. At noon on the 4th it turned more to northward, recurving on the 5th to the south of the Portuguese colony of Macao. Passing next very close in a north-northeast direction on the north of the colony, it disappeared most probably at a short distance from the east coast of China. We reproduce the following account from a report dealing with this typhoon, published in the Hongkong Daily Press, October 8, 1894:

> Deplorable as were the results of Friday's typhoon, the colony has reason to congratulate itself that the loss of life and damage to property were not much greater, as they certainly would have been had the storm burst upon the colony unexpectedly. In the matter of storm warnings the present generation enjoys advantages which were unknown in the earlier days of the colony. and the Causeway Bay breakwater has created a secure haven, though inadequate as regards capacity, for the small craft of the harbor. The storm was undoubtedly the most severe that has visited the colony since the memorable typhoon of 1874. At times the wind blew with as great force as on that occasion, but the gusts were less frequent and of shorter duration, while the direction was also more favorable, varying from northeast to southeast, and never getting to the north. Had the wind come from the last-mentioned quarter the damage would inevitably have been much more serious. The storm, morevoer, occurred during the day instead of in the nighttime, as in 1874, and it was consequently an easier matter to take precautions against it.
>
> In 1874, to quote from the description of the storm which appeared in these columns at the time, not a single ship in port escaped undamaged, and the casualties and loss of life—the latter estimated at over 2,000 souls—exceeded anything which had ever before been upon record. The city after the occurrence presented the appearance of a town which had been besieged. In all directions were roofless and shattered houses, crumbling walls, naked poles and rafters standing out gloomily against the leaden sky. The roads were strewn right and left with débris, wrecks of boats, and trees—some of gigantic size—torn up by the roots; and dead bodies in all directions were washed ashore. The tide was exceptionally high, which materially increased the amount of the damage

inflicted, and to the eastward a great deal of injury both to life and property was caused by the height of the water, which on the plain at East Point was on average about 4 feet high. The tale of calamity on the present occasion is a very much smaller one. The loss of life does not exceed a score, a few steam launches and native craft are all the vessels wrecked, and with a few exceptions the damage to house property consists in the stripping of tiles from the roofs, which made matters uncomfortable enough inside, owing to the rain that poured through, but the cost of repairs will not reach a sum of very great magnitude.

The record of the damage would no doubt have been a very different one had we been left without notice of the storm's approach, and we can not too highly appreciate the value of the warning telegraphed from Manila. In the days before the Bolinao cable was laid the colony had only the barometer to guide it as to the approach of storms, and how inadequate local observations are for this purpose was shown only as recently as the gale of the 24th and 25th ultimo. Manila sends us notices of the typhoons which pass in the neighborhood of the Philippines and informs us of their direction as long as their influence is felt there, and it is then the duty of the Hongkong Observatory to trace their onward progress. On the occasion mentioned, although information had been duly received from Manila that a storm was traveling from south-southeast to north-northwest the Observatory here left us to suppose that it was passing to the eastward of the colony, and it was not until the gale was actually upon us that the warning gun was fired, some loss of life and property occurring in consequence of the lateness of the notice. On the present occasion, however, as well as in the case of the other two gales which have been experienced during the last three weeks, the notice given by the Observatory was ample and enabled due precautions to be taken. Perhaps in the next annual report of the Director of the Observatory we may find some explanation of the failure of September 24, but the immediate lesson to be drawn from the occurrence is that it is better to err on the safe side in the matter of storm warnings.

We add to the above that the direction from south-southeast to north-northwest, which was given by the Observatory of Manila, had reference to the track of the typhoon so long as it lay to the east of Luzon. The telegram sent to Hongkong on September 22 at 6.30 p. m. read as follows:

The typhoon appears to be northeast of Manila very close to the northeast coast of Luzon; the direction seems to be from south-southeast to north-northwest, if it does not change.

CHARACTERISTIC QUALITIES OF CYCLONES WHICH CROSS THE MERIDIAN OF THE PLACE OF OBSERVATION CLOSE BY IN THE NORTH.

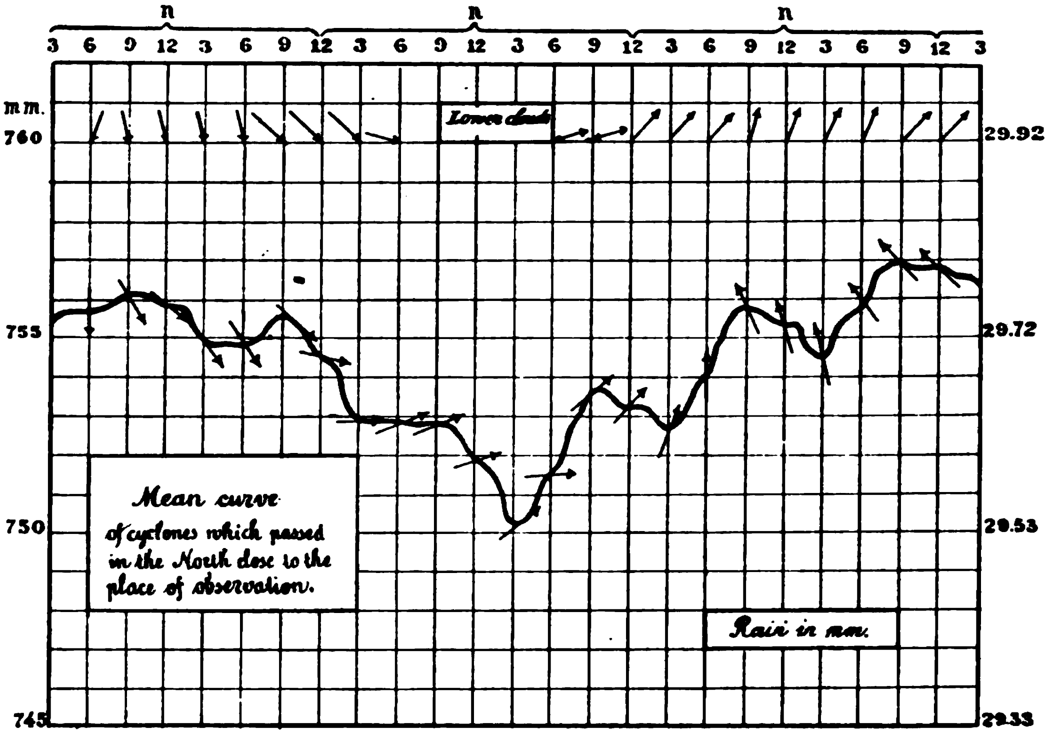
From the southern part of Luzon to the extreme south of the Archipelago the effects of the cyclones which move about in the north can be felt during the season of most frequent atmospheric disturbances, although in the months of the third group the general tracks or the zones of the trajectories of cyclones run through higher latitudes than those properly belonging to these regions. It will be of great practical utility to set forth the characteristics of those cyclones which travel in higher latitudes than those of the place of observation. As we have already characterized the typhoons which cross the meridian of the place of the observation far to the north, the only ones which remain are those which pass close by in the north.

Clouds.—With regard to the cirri, we refer to what has been said in the preceding chapter. The directions of the wind, the directions of the lower and perhaps of the intermediate clouds offer, as a rule, very useful hints as to atmospheric disturbances; in our case they offer *almost certain* indications. If the lower clouds come from the fourth quadrant (this direction being for the whole year an abnormal one) and if the barometer falls, even though slowly, this is an unmistakable sign that there is an atmospheric disturbance lying east of the observer. These signs appear nearly always half a day before the wind attains a great force or the barometrical minimum is observed, whatever may be the distance at which the storm will pass. In the case of which we are speaking the respective observations were made twenty hours previously.

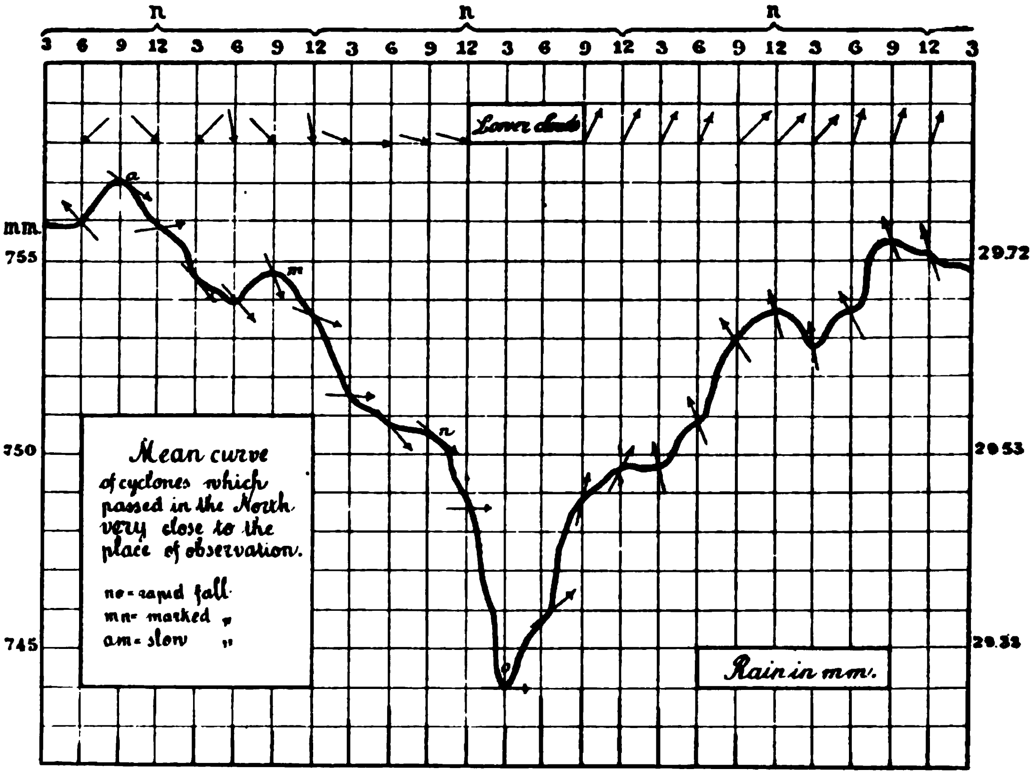
Practical rule.—If the motion of the clouds at the time of either the gradual, the distinct, or the rapid fall of the barometer veers round to the third quadrant, the center will pass by the north at a greater or less distance. If the clouds are changing their direction in this sense during the time of the gradual fall of the barometer, the center is passing at a considerable distance. If the shift, however, takes place during the distinct or rapid fall, then the center is crossing the meridian near or very near to the place of observation.

Rain.—Fine rain sets in when the clouds and winds are still coming from the fourth quadrant. Slight rain squalls recurring at intervals are, however, characteristic of cyclones which traverse the meridian in the north, if the directions of the wind and of the clouds are changing. The

Plate XLIX.



n
n
n
3 6 9 12 3 6 9 12 3 6 9 12 3 6 9 12 3 6 9 12 3 6 9 12 3
mm.
760
755
750
745
29.92
29.72
29.53
29.33
Lower clouds
Mean curve of cyclones which passed in the North close to the place of observation.
Rain in mm.



n
n
n
3 6 9 12 3 6 9 12 3 6 9 12 3 6 9 12 3 6 9 12 3 6 9 12 3
mm.
755
750
745
29.72
29.53
29.33
Lower clouds
a
m
n
Mean curve of cyclones which passed in the North very close to the place of observation.
n = rapid fall
m = marked "
a = slow "
Rain in mm.

amount and frequency of the rain are not signs for the distance at which a cyclone is passing. Both show a great changeableness, which doubtless depends on the different degrees of saturation at the places which are struck by the cyclonic winds. The graphic representations of the cyclones which pass by to the north of the place (Pl. XLIX) and the characteristic cyclones hitherto discussed show that the rain falls more heavily, and correspondingly the rain squalls become more frequent, if the winds are already steadily blowing from the third quadrant, but often not before the barometer has already begun to rise. This happens not only at Manila, where the geographical position has, no doubt, some influence, but also at most other places in the Archipelago.

Barometer.—The barometer begins to fall slowly when the wind and clouds commence to take the direction of the fourth quadrant, and generally a day before the greatest force of the wind. The distinct fall occurs before the clouds veer round to the third quadrant; the rapid fall is usually only noticed with centers whose minimum distances do not vary much from those passing by very close. Should the slow fall occur a long while before the center passes, the amplitude of the daily oscillation is usually still great at the beginning, decreasing by degrees and disappearing altogether during the rapid fall, should this come on at all. If the slow fall occurs one or two days before the absolute minimum, the daily variation will remain below the normal one, and in this case the displacement of the tropical hours for maximum and minimum of the day is greater during the distinct fall. We get a good idea of the difference between the curves of a gradual, a distinct, and a rapid fall by comparing them with a normal curve. If we compare the latter with a curve of a gradual fall they run almost parallel, but the last-named curve is constantly 1 to 2 millimeters (0.04 to 0.08 inch) lower than the first one. The difference grows by degrees greater as the hours for the maximum and minimum change. In the case of the curve of a distinct fall the form is on the whole still maintained, but the differences and the displacements of the epochs for the extremes are greater. With a rapid fall the similarity with the normal curve has quite disappeared; an inclined line, which exhibits at most very slight variations, takes the place of the double wave.

Wind.—Just like the clouds, the wind commences to blow from the fourth quadrant, but it does not keep so steady, being at the time of the gradual fall sometimes still influenced by the sea breeze. If, however, the place be in zone A, the wind is of great use, taken together with the other indications. About the veering of the wind we can say almost the same as about that of the clouds. If the wind comes from the third quadrant and from the south this is a sign that the center is passing farther, more or less, from the place of observation, but we must always watch the barometer.

GRAPHICAL REPRESENTATION OF THE MEAN CHANGES IN SOME METEOROLOGICAL ELEMENTS WHILE THE CENTER IS PASSING NEAR IN THE NORTH (PLATE XLIX, UPPER HALF).

We have brought together into mean values the meteorological elements which have been collected while some cyclones were passing close in the north, and drawn the plate (XLIX, upper part) accordingly. We will explain briefly the plate.

Clouds.—If the clouds come already from the fourth quadrant, then thirty-six hours before the absolute minimum sets in they veer slowly round to the third quadrant and have a steady westerly direction until six hours before the absolute minimum. The shift to the south also takes place gradually at the time when the barometer begins to rise again.

Rain.—The rain becomes more frequent and heavy as soon as the wind has an inclination toward the third quadrant; it is heaviest with a west-southwest wind, but it falls only intermittently as the wind, veering through the third quadrant, approaches a south direction.

Barometer.—The gradual fall commences thirty-six to eighteen hours, the distinct eighteen hours, and the rapid fall six hours before the absolute minimum. Of the cyclones which were employed for the construction of the mean curve, many crossed the meridian at a distance of more than 90 miles, which is the mean of 60 and 120 miles—that is, the boundaries of zone B. The rapid fall has, therefore, but little chance to be exhibited in the curve.

Wind.—As the force of the wind changes very much, and besides this often does not correspond to the barometrical gradient, at least not during the gradual and distinct falls, we have contented ourselves with showing the direction only. By these means the observer, in connection with the fall of the barometer, is enabled to follow the movements of the center. The wind changes its direction a few hours before the clouds.

GRAPHICAL REPRESENTATIONS OF THE MEAN MOVEMENT OF SOME METEOROLOGICAL ELEMENTS WHILE THE CENTER IS PASSING VERY CLOSE IN THE NORTH (PLATE XLIX, LOWER HALF).

Clouds.—As in the preceding case the clouds come from the north long before the outbreak of the cyclone, but they are not so steady, because they frequently veer round to the first quadrant. Experience shows this peculiarity of the cyclones which are passing very close to the northward. This is the reason why an observer, when a cyclone threatens from the southeast, can only with difficulty decide whether the storm will cross the meridian to the south or north of his station. If the clouds have a northeast direction, veering to east-northeast and east, he may be sure that the typhoon will pass by to the south, as was the case with the terrible cyclone which traversed the interinsular seas, passed over the Visayas and also the south of Luzon on October 12 and 13, 1897. The opposite will take place when the direction of the lower clouds is from the fourth quadrant.

Barometer.—In the drawing the three portions of the curve—the gradual, distinct, and rapid fall—are so well defined that it is not necessary to say much about them. But we wish to point out that it is of the greatest importance to the observer to get accustomed to notice the slow descent of the barometer. If he succeeds in this it will be impossible for him to be surprised by the close approach of a cyclone, especially if the fall follows upon a succession of fine days. If the typhoons follow each other at short intervals the slow descent is not easily recognized, but the observer will be on his guard if he finds that the barometer does not reach its normal level.

Wind.—If a cyclone is on the point of passing very close in the north, the wind very seldom changes its direction to the first quadrant. If this sort of shift has once taken place, the wind will not reach northeast permanently; it keeps in the north-northeast, but there is always an inclination, as the figure shows, to veer to the third quadrant. It depends on the distance of the center whether the shift is rapid or slow. If we compare the preceding figure with this we shall find that, with a cyclone which passes close, the wind will shift to the westward much sooner than with one which passes very close to the point of observation. In the first case the wind comes from the west twelve hours before the arrival of the absolute minimum of pressure, but in the second only three hours before.

Rain.—When a cyclone passes very close to the point of observation the amount of rain is very great. It increases as the barometer rises, as the figure shows. Although the observations refer specially to Manila, the sequence of the phenomena seems to be much the same all through the Archipelago.

We did not give a typical instance of a typhoon passing very near in the north, because these storms do not present great differences from those which pass near, except the points which we have just noted. Besides, the type which we describe in the following chapter may well be taken as an example of this kind, since the phenomena preceding the passage of the vortex were the same which precede its passage *very near* in the north.

CHAPTER III.—THE CYCLONE OF OCTOBER 20, 1882.

PLATE L.

Fortunately it seldom happens that the actual center of a cyclone passes over a given place. We quote, nevertheless, such an example, for in this case only the phenomenon develops all its grandeur and its dire effects.

Some cyclones the vortices of which passed over Manila.—The typhoons of this nature of which we have scientific observations are six in number:

1. The cyclone of October 22 and 23, 1831, called by Reid and Piddington the "Manila typhoon," was extraordinarily destructive at Manila and Cavite, its center passing over the Bay of Manila, crossing the meridian of the capital to the southward.

2. The typhoon of October 11 to 13, 1839, very much resembled the preceding and was also very violent.

3. The cyclone of August 4 to 5, 1839, passed very close by the north. Manila came to lie on a chord of its central calm.

4. The typhoon of September 25 to 27, 1840, closely resembled No. 3.

5. The cyclone of September 5 to 9, 1847, likewise passed very close in the north.

6. We finally quote the famous typhoon of October 20, 1882, which has been most carefully observed. It passed exceedingly close by to the north, Manila lying on a chord of the central region. This typhoon we take as a type, utilizing the excellent observations made during its passage and published by Fr. Faura in the essay "Ligeros apuntes sobre el huracán del 20 de Octubre de 1882."

Classification.—This typhoon belongs to the second group, to the cyclones of Luzon and the Chinese Sea. While crossing Luzon the mean velocity was 15.8 nautical miles per hour. The distance of the center could not be ascertained, although the veering of the wind showed that it would pass on the north side. The mean inclination of the track to the meridian was W. 20° N.

First indications.—The first indications showed themselves at noon on the 19th of October, 1882, about twenty-four hours before the arrival of the center, by a fall of the barometer to 756.50 millimeters (29.78 inches). It was therefore rather late when the presence of the typhoon could be determined by the first indications. The high clouds, the direction of which on other occasions gives warning of the storm two or three days before the arrival of the center, were not observable.

In contrast to this, the high clouds of the typhoon which passed very close to Cavite on November 5, 1882, were already observed at 9 a. m. on the 3d, and therefore fifty-one hours before the center. On this latter occasion the cirro-strati appeared as long ribbons, fastened to each other like a row of fir cones, with a convergence to east-southeast; the velocity amounted to 9.6 miles per hour.

The failure to observe the first direct signs of the storm in our case can not be explained by saying that they passed unheeded. It rather seems that they did not appear, for in the account quoted we read:

> Up to that hour (noon of October 19) there had appeared in the heavens neither the cirro-strati, these heralds of the storm who so well guide the observer in ascertaining the bearing of the vortex and the direction in which it will advance, nor the cirrus veil and solar halos which are never wanting in the neighborhood of the storm; nor the characteristic tints of the clouds at sunset, which, together with the cirro-strati, enable us to fix with almost mathematical precision the center of the arc formed by the hurricane bar as soon as the latter appears

on the horizon, and thus to ascertain with close approximation, not only the presence of the enemy, but also the point at which he will attack us.

The whole is explained by a careful examination of the meteorological records of the two days preceding the passage of the vortex. At sunset on the 18th nearly the whole sky was covered by nimbi, hence neither special tints nor directions of the higher clouds could be observed. The conditions recurred at sunset on the 19th. We believe that this instance goes far in explaining why it is that in higher latitudes the cirri are hardly ever seen as a precursory sign of a cyclone.

The first indications might, however, have been taken from the slow fall of the barometer, as becomes evident if we compare the successive barometric observations made on October 17–20. The differences in millimeters between the six daily readings of the barometer (which were at that time made at the Observatory) form the following table:

Day.	6 a. m.	9 a. m.	Noon.	3 p. m.	6 p. m.	9 p. m.
Oct. 17–18	−0.24	+0.30	+ 0.91	+0.68	+1.11	+0.61
Oct. 18–19	+1.80	+1.91	+ 1.87	+1.05	+1.63	+2.20
Oct. 19–20	+5.48	+9.86	+27.90	--------	--------	--------

Hence we see that at 9 o'clock on the 18th, or fifty-one hours before the center passed, the barometer began to fall slowly and uniformly. The difference up to 9 a. m. on the 19th amounted to almost 2 millimeters (0.08 inch); at 9 p. m. on the same day it was already greater than 2 millimeters (0.08 inch).

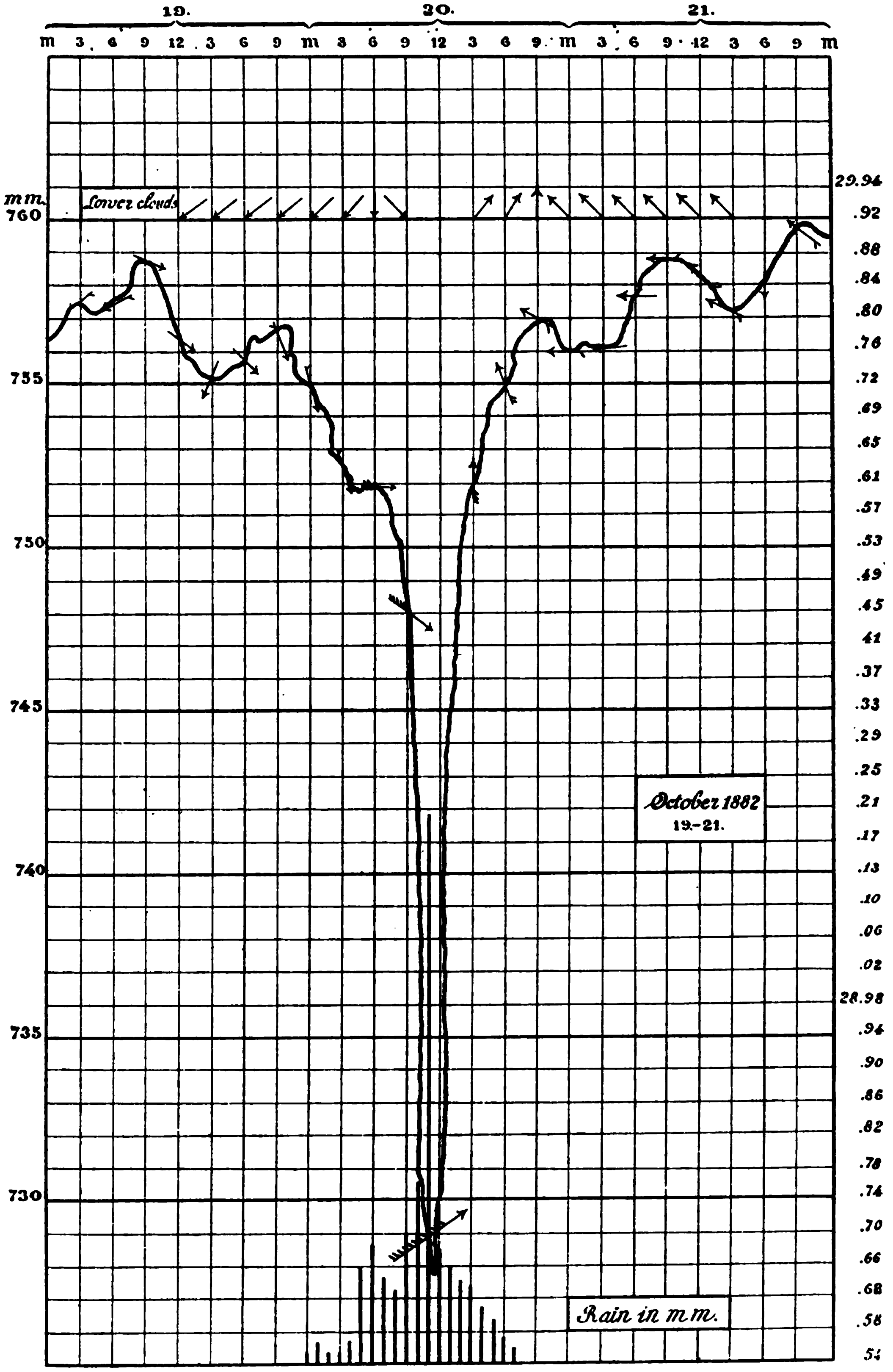
This instance clearly demonstrates how extremely important it is to watch carefully the slow fall of the barometer, which in this case could have partly supplied the lack of other precursory signs which generally are watched for more carefully, giving about forty hours in advance the warning that most probably a typhoon was approaching in some way or other.

Observations which were made before and after the center had passed.—These are partly taken from the self-registering apparatus but partly they are direct observations, comprising the time from noon on the 19th to 10 p. m. on the 20th.

OBSERVATIONS DURING THE CYCLONE OF OCTOBER 20, 1882.

Date.		Barometer.	Thermometer (Celsius).	Relative humidity.	Wind.		Clouds.					Rain.	Remarks.
Day.	Hour.				Direction.	Force, 1-12.	Amount, 1-10.	Higher. Form.	Higher. Direction.	Lower. Form.	Lower. Direction.		
				Perct.								*Mm.*	
Oct. 19	Noon	756.40	32.0	62.2	NW.	1	4	Ci.-Cu.	NE.	Cu.	NE.	------	
	1.00 p. m.	56.00	31.6	63.5	W.	2	7	------	------	Cu.-S.	NE.	------	
	2.00 p. m.	55.40	32.2	59.0	NNW.	2	7	------	------	Cu.-S.	NE.	------	
	3.00 p. m.	55.40	31.6	60.0	NNE.	0	9	Ci.-Cu.	E.	Cu.-N.	NE.	------	
	4.00 p. m.	55.20	30.6	64.0	NNE.	0	9	------	------	Cu.-N.	NE.	------	
	5.00 p. m.	55.60	28.7	78.0	NE.	0	9	------	------	Cu.-N.	NE.	------	Velocity of clouds seems to increase.
	6.00 p. m.	55.80	27.7	87.2	NW.	0	9	------	------	N.	NE.	------	
	7.00 p. m.	56.45	24.0	90.0	N.	4	10	------	------	N.	NE.	------	No special coloration of clouds at sunset; 8 p. m. lightning in S.W.
	8.00 p. m.	56.40	24.0	91.0	NW.	5	9	------	------	Cu.-N.	NE.	------	
	9.00 p. m.	56.60	24.0	90.0	NNW.	2	9	------	------	Cu.-N.	NE.	------	
	10.00 p. m.	56.80	24.0	90.8	NNE.	2	9	------	------	Cu.-N.	NE.	------	Sky clouding, especially in E.
	11.00 p. m.	55.40	23.8	92.1	N.	2	9	------	------	Cu.-N.	NE.	------	
	Midnight.	55.00	24.0	95.7	NNW.	2	9	------	------	Cu.-N.	NE.	5.0	All clouded, except small part in western horizon.
Oct. 20	1.00 a. m.	54.80	23.8	96.8	N.	0	9	------	------	Cu.-N.	NNE.	2.0	Do.
	2.00 a. m.	54.05	24.4	95.6	NNW.	4	9	------	------	Cu.-N.	NNE.	2.0	Do.
	3.00 a. m.	52.70	24.2	95.0	NNW.	4	9	------	------	Cu.-N.	NNE.	4.0	Do.
	4.00 a. m.	52.50	24.0	95.0	NW.	4	10	------	------	N.	N. by NE.	7.0	N. and Cu.-N.
	5.00 a. m.	52.38	23.8	94.1	NW.	5	10	------	------	N.	N.	15.2	Do.
	6.00 a. m.	51.97	24.0	94.0	WNW.	6	10	------	------	N.	N.	12.0	Whole sky covered with N.; velocity of wind, 12 meters per second.

Plate L.



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OBSERVATIONS DURING THE CYCLONE OF OCTOBER 20, 1882—Continued.

Date.		Barometer.	Thermometer (Celsius).	Relative humidity.	Wind.		Clouds.					Rain.	Remarks.
Day.	Hour.				Direction.	Force, 1-12	Amount, 1-10.	Higher.		Lower.			
								Form.	Direction.	Form.	Direction.		
				Per ct.								Mm.	
Oct. 20	7.00 a.m.	751.07	24.6	87.0	WNW.	9	10	------	------	N.	(?)	15.0	Velocity of wind, 19.8 meters per second; direction of clouds not discernible.
	8.00 a.m.	50.82	24.6	88.2	NW.	6	10	------	------	N.	(?)	22.0	Velocity of wind, 12.1 meters per second; direction of clouds not discernible.
	9.00 a.m.	48.52	24.3	91.9	WNW.	10	10	------	------	N.	(?)	------	Velocity of wind, 25.5 meters per second.
	10.00 a.m.	44.51	23.8	95.0	WNW.	12	10	------	------	N.	(?)	30.0	Velocity of wind, 40 meters per second.
	10.30 a.m.	37.10	23.8	98.0	WNW.	12	10	------	------	N.	(?)	------	Velocity of wind, 52.2 meters per second.
	11.00 a.m.	32.39	23.8	99.7	WNW.	12	10	------	------	N.	(?)	40.0	Velocity of wind, 53.8 meters per second; 11.00-11.46 frequent and vivid lightning.
	11.40 a.m.	27.60	31.6	49.7	W.	8	10	------	------	N.	(?)	------	Velocity of wind, 5.3 meters per second; 11.46 entrance into relative calm; 11.52 absolute calm for 2 minutes.[1]
	Noon	29.00	29.8	100	SW.	12	10	------	------	N.	(?)	20.0	Velocity of wind, 53 meters per second.
	1.00 p.m.	43.62	24.4	100	S. by SE.	12	10	------	------	N.	SSW.	17.5	Velocity of wind, 40 meters per second.
	2.00 p.m.	49.84	24.8	97.8	S. by SE.	11	10	------	------	N.	SSW.	15.0	Velocity of wind, 28.6 meters per second.
	3.00 p.m.	50.16	25.0	86.9	S.	6	10	------	------	N.	SSW.	12.0	Velocity of wind, 10.5 meters per second.
	4.00 p.m.	51.90	25.0	83.5	S. by SE.	5	10	------	------	N.	SSW.	10.0	Veloitcy of wind, 9.7 meters per second.
	5.00 p.m.	52.60	25.2	86.5	S.	5	9	------	------	N.	SSW.	7.9	
	6.00 p.m.	54.90	25.0	88.3	SSE.	5	9	------	------	N.	S.	3.0	
	7.00 p.m.	55.60	25.0	89.0	SSE.	5	9	------	------	N.	S.	3.0	
	8.00 p.m.	56.35	25.0	91.9	ESE.	4	9	------	------	N.	S.	------	
	9.00 p.m.	56.70	25.3	95.0	ESE.	3	9	------	------	N.	S.	------	
	10.00 p.m.	57.00	25.9	95.0	------	------	9	------	------	------	------	------	

[1] We call special attention to the sudden rise in temperature and fall in relative humidity.

The observations are of so great value that they deserve a particular discussion.

Clouds.—Commencing with noon on the 19th till 1 a. m. on the 20th (when they began to veer somewhat to the north), the lower clouds came from northeast, without the least deviation. The northeast direction of the clouds is not uncommon if a cyclone passes very close to the place of observation by the north. But if this direction is still very steady after the barometer has already commenced to fall decidedly, there is very great probability that the center will pass over the place itself. Besides, the direction of the clouds was not normal for that time of the year, a circumstance which already by itself makes it necessary for the observer to be very careful. The slow change of the direction during the very decided fall of the barometer was another indication of the fact that Manila lay in the track of the cyclone. This veering also confirms the thought which we expressed when we said that the more pronounced is the veering toward the fourth quadrant and the west the greater is the distance at which the center will pass to the northward. This is shown by the mean curves which correspond to the cyclones passing to the northward. If a center passes close to the north the clouds from the fourth quadrant north-northwest will be observed as much as thirty hours before the absolute minimum, but if the center should pass very close to the north the clouds frequently turn first toward the first quadrant and do not come steadily from the fourth quadrant until about eighteen hours before the barometer has reached its lowest reading. In our case, in which the vortex passed so closely to the place that the latter lay on a chord traversing the vortical region to the south of its center, the clouds came from the fourth quadrant scarcely five hours before the lowest minimum.

At the beginning, while the barometer is still falling slowly, the three cases show the same characteristics.

Rain.—The rain began at the time of the distinct fall of the barometer, it was raining in torrents near the center when the wind was coming from the northwest, and it rained still heavier when the wind went to north-northwest. The quantity of rain decreased as the barometer rose.

Barometer.—The movement of the barometer in this baguio is exceedingly interesting. We have already said that the barometer commenced to fall slowly at 9 a. m. on the 18th. From that hour till 10 p. m. on the 19th the barometer showed but a very gradual fall; the daily variation was still perceptible, only the amount of the fall increased while that of the rise decreased. This is a magnificent illustration of what we have called the second partial alteration.

At 10 p. m. on the 19th the pronounced fall commenced and lasted till 6 a. m. on the 20th, at which time the rapid fall commenced. In the table is is stated that the barometrical minimum took place at 11.40 a. m., six minutes before the commencement of the relative and twelve minutes before the commencement of the absolute calm. As soon as the zone of relative calm was reached again, the barometer began to rise suddenly, so that from 11.54 to 12.02 it had reached a height of 730 millimeters (28.74 inches); the wind was at the same time blowing with its former fury, but it had gone to the southwest. An examination of the barometric curve of this hurricane shows that the second partial change lasted till 6 a. m. on the 20th, and then the first total change set in until the passing of the center.

Winds.—From the afternoon of the 18th the direction of the wind varied between northeast and northwest; on the morning of the 19th there was no sea breeze, and this in connection with the gradual fall of the barometer aroused suspicion, which increased when, at noon on the 19th, the wind commenced to blow steadily from between north-northeast and northwest. It must be specially mentioned that no wind coming from the first quadrant was recorded when the squalls began to blow, and from this fact we concluded that Manila had entered the outer zone of the cyclone. We had some wind from the north when the barometer fell to 754.80 millimeters (29.72 inches), no doubt in consequence of the squalls. The latter, as we have repeatedly observed, show a tendency to lessen the convergence of the wind as soon as the place has entered the zone A. If we imagine a line drawn on the disc of the cyclonometer cutting the central region parallel to the central arrow after this has been orientated to point from E. 20° S. to W. 20° N., we shall find that on the southern side of this line there is a remarkable conformity between the wind arrows drawn on the disc and the wind directions which prevailed in the cyclone.

The special circumstances of this typhoon almost force us to touch upon some interesting questions. This will assist us in obtaining a fuller knowledge of the nature of these terrible meteors, which is best understood if they are studied in close proximity. It will suffice to give a few paragraphs from the account already quoted.

The direction and velocity of the whole body of the storm.—At 5 a. m. of the 20th the following warning was cabled to Hongkong: "A typhoon has reached Manila from the E., direction WNW." This warning was not quite accurate, but was very near the truth, as is proved by the observations of Manila and on board the training ship of the Guardia Marinas ***Maria de Molina,*** which was at anchor in the harbor of Olongapo, near Subic. Like Manila, this place lay on the trajectory of the vortical calm, and even more so than Manila, since the passage was almost central, the center of the vortex passing just slightly to the north of the ship, while at Manila it crossed at some distance. Now, the line joining Manila and Olongapo runs almost directly east-southeast to west-northwest with a slight deviation toward north. Since there is no better means of determining the track of a typhoon than the successive positions of the center, if its passage over given localities has been observed, we are able to ascertain the path followed by the cyclone in question across the Archipelago. Supposing that the direction remained constant, the storm entered the Archipelago by the Catanduanes Islands, thence the vortex passed over Daet, the capital of Camarines Norte, and Manila and finally reached the China Sea at Subic. The supposition of a constant direction can not be very far from the truth, considering the violence of the storm, which was such that the obstacles offered by our island could hardly have sufficed to divert it from its path.

In order to determine the velocity of the typoon we have the following data: The center passed Manila at the time of the lowest barometrical reading, which lasted up to 11.52. At Olongapo, which lies to the west-northwest of Manila, the lowest barometrical reading was noticed at 2.15 p. m. The time which elapsed amounted to two hours and twenty-five minutes; taking into account the difference in longitude the velocity was, therefore, about 19 nautical miles. This is the highest velocity which we have been able to observe hitherto. At the time at which the first indication of the cyclone became noticeable it must have been still at a distance of about 370 miles.

We are not in a position to say whether the typhoon, after reaching the China Sea, kept its direction or not; we have no observations for this.

From a study of the table we see that the barometer fell much more slowly than it afterwards rose. The last two hours of the descent seem to form an exception, since their slope looks like that of the rise, but on closer inspection we find that even their inclination is somewhat less steep than that of the ascent. The immediate conclusion is that the isobars around the center were not circular; they were further apart in the anterior semicircle than in the posterior, forming a sort of an ellipse[1], the posterior focus of which was occupied by the center.

But besides this deduction drawn from the examination of the isobars, we hold that the observations corroborate the theory of the convergent winds and make us see how far these were from being circular, even in this case when there was so extraordinary a gradient.

We take for example the hurricane at the moment when the vortex passed over Manila at 12 noon. Let us lay down the points, at different distances from the center, from which we have observations. These places of observation are: Sual in the northwest by north; Subic in the west-northwest; San Luis de la Pampanga in the north by northwest; Puerto de Mariveles in the west-southwest; Calamba in the south-southeast; and Punta Santiago in the south-southwest, as regards Manila. Had the winds taken a circular course, they would have blown necessarily at Sual from northeast by east, at Subic from north-northeast, at Mariveles from north-northwest, at Calamba from west-southwest, at San Luis de la Pampanga from east by north, and at Punta Santiago from west-northwest. But they were north at Sual and Subic, west-southwest at Mariveles, southwest at Calamba and Punta Santiago, and northeast at San Luis de la Pampanga. To judge by this, the wind directions were not circular but convergent. We believe these facts to be sufficient to corroborate the theory of convergent winds and to completely destroy the much-talked-of theory of circular winds.

The effects of the cyclone.—The terrific violence of the hurricane is that part of the phenomenon which is most deeply engraven in the souls of all of us who have witnessed its passage—the part in whose description it is well-nigh impossible to maintain the matter-of-fact language of scientific analysis. Too recent are the terrifying impressions to be recalled without emotion; still heaped up all around us are the sad ruins to which this rod of divine justice has reduced alike the straw-thatched hut of the lowly Indio and the comfortable home of the influential citizen. Moreover, no observational data can compare with the eloquence of the facts which each one of us has witnessed and was—in spite of himself—compelled to experience in all their detail.

"Who can form an adequate idea of the violence of the storm from the appalling figures reached by the anemographic curve, which seemed eager to outdo in an inversed ratio the successive descending jumps of the barographic record? No one will be able to appreciate the tremendous atmospheric turmoil like he who, for two hours and a half, heard the awe-inspiring roar of the tempest and felt the house that sheltered him tremble and rock under the powerful onslaught of the squalls, ever increasing in fury. At such moments we feel our own insignificance as compared to so imposing a manifestation of the Supreme Power, who, with a slight disturbance of the atmospheric equilibrium, can chastise us so severely. Under circumstances so critical it is a hard and painful task for the observer to attempt penetrating the secrets of nature. The best instruments are usually put out of action or break down under the destructive force of the elements. Moreover, when the most solid and substantial buildings crack and sway under the impulse of the hurricane; when roofs are carried off and torn to pieces; when heavy sheets of metal whirl through the air like feathers and mighty trees fly great distances as if hurled from a gigantic, invisible catapult, then every mortal is naturally inclined to bow his head and adore the majesty of God who is passing before him with a slight display of His power. But let us leave the description of supreme moments like these to more gifted pens and, entering upon scientific ground, try to discover the causes which contributed to make this storm so disastrous."

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[1] Or rather a system of ellipses having one, the posterior, focus in common.

Position of Manila relative to the center.—We are convinced that at the moment the cyclone burst over Manila we were situated at that point of the storm at which the violence of the winds was most formidable and destructive. Our reasons are (1) the barometric slope was unusually steep; (2) the wind was especially powerful near the surface; (3) we were for a time precisely at the point at which the winds began to take an upward direction.

As to the first, a storm is to be dreaded as soon as the barometric gradient exceeds 0.03 millimeter per geographical league. But here at Manila it was on this occasion 1.5 millimeters per league,[1] hence five times the amount which theory assigns as sufficient to cause a severe storm.

The steep barometric gradient, however, accounts only partly for the destructive character of the wind. Fortunately we have the other fact that the barometer rose much more rapidly than it had fallen—so much so, that half an hour after the passing of the center the winds began to subside in a most extraordinary manner and at 1 p. m. had no greater force than they usually exhibit during the ordinary storms of our Archipelago. This gives us a clew as to another cause which may help to explain the point in question. This cause we find in the great inclination of the storm's axis in the direction of the cyclonic trajectory. Without this assumption it is simply impossible to understand how, with a pressure slope so steep on either side of the vortex, the winds could rage for fully an hour and a half before our entering into the vortex and for only half an hour after the passing of the same, afterwards abating in so remarkable a way.

Our readers will remember that at 12.30 p. m. we published the following bulletin: "The vortex has passed; there will be SW. winds, violent but of short duration. Soon they will relent very much."

They will also remember that this prediction was exactly fulfilled. We based the same on the observation that the rain clouds, which a few moments before had been swept along almost touching the ground and had made it impossible to see anything even at short distances, suddenly rose, thus indicating that at our position within the posterior semicircle the winds had an upward direction.

That Manila was in that part of the storm in which the winds commenced their ascending course—a circumstance largely responsible for their destructiveness—is amply proved by the many objects which were seen flying through the air, some very heavy ones being carried to considerable heights and distances. We could give a great number of instances, but content ourselves with narrating one which unfortunately proved disastrous to the Observatory. The latter lies 34 meters above sea level. At a distance of some 200 meters was a group of palm trees. A few minutes to 11 a. m. the wind uprooted one of these, carried it up to the level of the Observatory platform, and hurled it against the castiron pillar containing the transmission of the anemograph, thus wrecking the apparatus.

During the typhoon of August 19, 1881, the wind reached the high velocity of 42 and 44 meters per second and maintained the same almost constantly for eight hours. Nevertheless, the destruction caused by the cyclone was but small, because the wind at our station had then a descending direction. One of the anemometers was blown off its axis and fell nearly perpendicularly to the ground; had the direction of the wind been horizontal or ascending the anemometer would have blown far away. During the last typhoon, on the contrary, objects, no matter how heavy they were, flew about like so many feathers, being carried to great heights and distances. In one word, Manila found itself at the point upon which the storm concentrated its greatest fury.

After the storm left Manila its violence diminished rapidly. We need only mention the barometer readings at Manila and on board the *Maria de Molina.* Here the minimum was 727 millimeters (28.62 inches), on board the ship it was 734 millimeters (28.90 inches). Since the instrumental error of the ship's barometer amounted to +2 millimeters, the minimum was in reality 736 millimeters, a difference of 9 millimeters. This is about the amount of barometric fall at Manila during ordinary, though violent, hurricanes.

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[1] According to the international system (Vienna, 1873) above values are 1.13 millimeters = 0.044 inch and 5.63 millimeters = 0.222 inch, respectively.

We need not again describe the phenomena observed during the transit of the vortex, since we have discussed them sufficiently in Part I, Chapter V, page 57.

CHAPTER IV. CYCLONES WHICH PASS VERY CLOSE TO A PLACE BY THE SOUTH.

CYCLONE OF OCTOBER 28 AND 29, 1883 (PLATE LI).

Classification.—We take as a type of the cyclones which pass very close by the south that which was felt in Manila on October 28 and 29, 1883. This cyclone belongs to the second group, type 7. It crossed the Archipelago with a regular mean velocity (10.4 nautical miles per hour) in a direction W. 22° N. (WNW.). The center remained off Manila at a distance of about 30 miles. We have chosen this typhoon, as it instances the slow fall of the barometer as a precursory sign.

The first indications.—At 1 p. m. on the 27th, and therefore thirty-six hours before the center had reached the least distance from Manila, convergent cirrus streaks were noticed in the E.–SE. which maintained their direction and convergence up to the time of sunset. The idea was hence justified that the center of a cyclone lay in that direction.

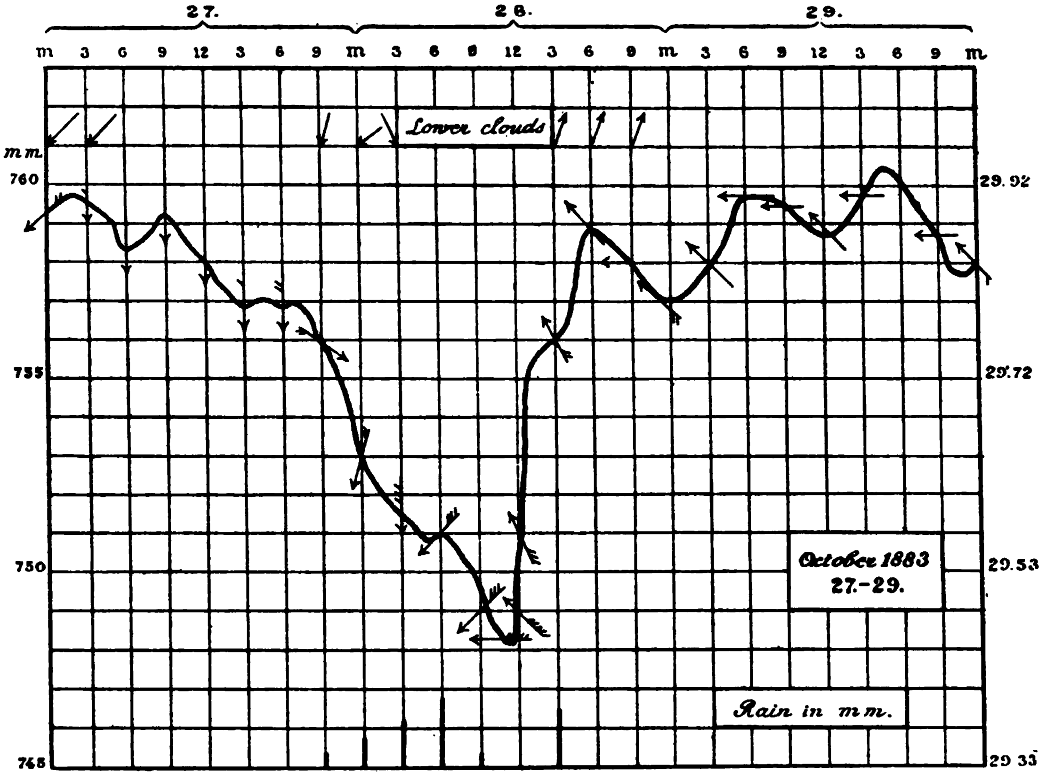
The clouds.—The cirri came from east-southeast with a regular velocity, and the lower clouds, strato-cumuli, constantly from the northeast.

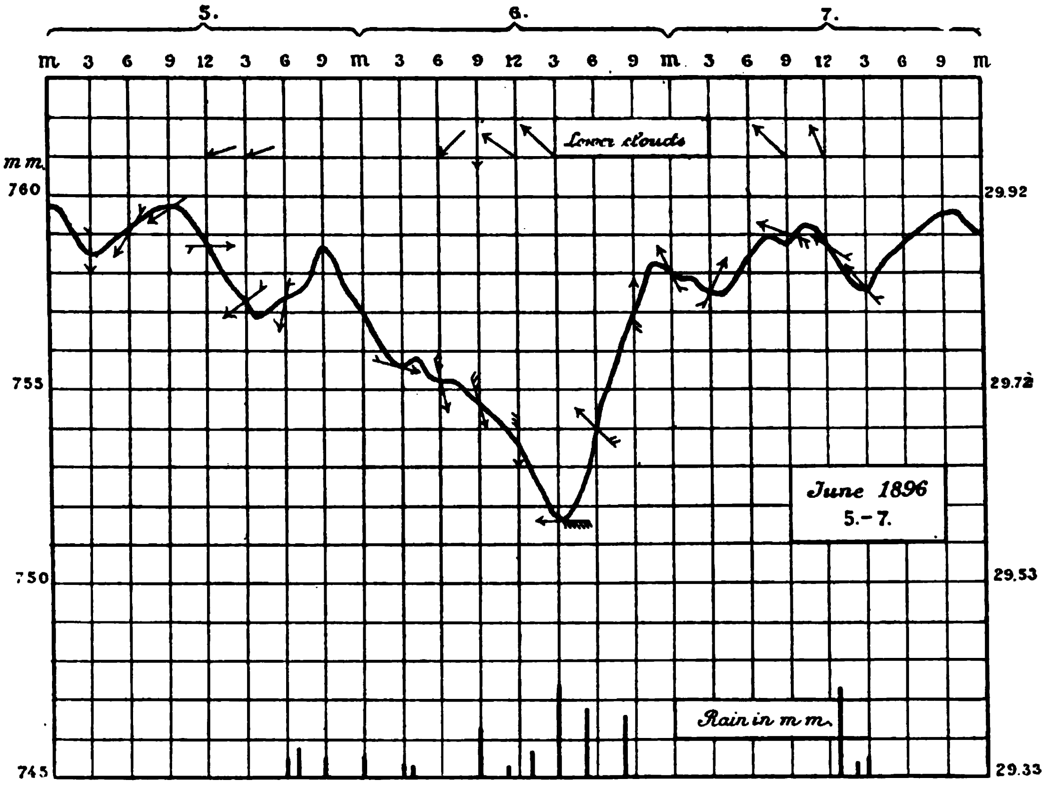
COMPARISON OF BAROMETER READINGS AT CORRESPONDING HOUR.

Date.		Barometer.	Date.		Barometer.	Barometric movement per hour.	Difference in 24 hours.
Day.	Hour.		Day.	Hour.			
		Mm.			*Mm.*		*Mm.*
Oct. 26	6.00 p. m.	759.92	Oct. 27	6.00 p. m.	758.57	--------	— 1.35
	7.00 p. m.	60.33		7.00 p. m.	58.69	+0.12	— 1.64
	8.00 p. m.	60.97		8.00 p. m.	59.15	+0.46	— 1.82
	9.00 p. m.	61.12		9.00 p. m.	59.27	+0.12	— 1.85
	10.00 p. m.	61.18		10.00 p. m.	59.20	+0.07	— 1.98
	11.00 p. m.	61.19		11.00 p. m.	59.10	—0.10	— 2.09
	Midnight	60.89		Midnight	58.76	—0.34	— 2.13
Oct. 27	1.00 a. m.	60.50	Oct. 28	1.00 a. m.	58.28	—0.48	— 2.22
	2.00 a. m.	60.18		2.00 a. m.	57.79	—0.49	— 2.49
	3.00 a. m.	59.77		3.00 a. m.	57.03	—0.76	— 2.74
	4.00 a. m.	59.39		4.00 a. m.	56.85	—0.18	— 2.54
	5.00 a. m.	59.45		5.00 a. m.	56.82	—0.03	— 2.63
	6.00 a. m.	60.14		6.00 a. m.	56.79	—0.03	— 3.35
	7.00 a. m.	60.53		7.00 a. m.	56.96	+0.17	— 3.57
	8.00 a. m.	61.09		8.00 a. m.	56.80	—0.16	— 4.29
	9.00 a. m.	61.27		9.00 a. m.	56.96	+0.16	— 4.31
	10.00 a. m.	61.12		10.00 a. m.	56.62	—0.34	— 4.50
	11.00 a. m.	60.70		11.00 a. m.	56.01	—0.61	— 4.69
	Noon	59.98		Noon	55.30	—0.71	— 4.68
	1.00 p. m.	59.09		1.00 p. m.	54.10	—1.20	— 4.99
	2.00 p. m.	58.66		2.00 p. m.	52.54	—1.56	— 6.21
	3.00 p. m.	58.49		3.00 p. m.	51.82	—0.72	— 6.67
	4.00 p. m.	58.24		4.00 p. m.	51.84	+0.02	— 6.60
	5.00 p. m.	58.10		5.00 p. m.	51.69	—0.15	— 6.51
	6.00 p. m.	58.57		6.00 p. m.	51.58	—0.11	— 6.99
	7.00 p. m.	58.69		7.00 p. m.	50.80	—0.78	— 7.89
	8.00 p. m.	59.15		8.00 p. m.	51.15	+0.35	— 8.00
	9.00 p. m.	59.27		9.00 p. m.	50.72	—0.42	— 8.55
	10.00 p. m.	59.20		10.00 p. m.	50.03	—0.69	— 9.17
	11.00 p. m.	59.10		11.00 p. m.	48.97	—1.06	—10.13
	Midnight	58.76		Midnight	48.54	—0.43	—10.22

The barometer.—The mean barometrical height was 760.70 millimeters (29.949 inches) on the 26th and 759.56 millimeters (29.906 inches) on the 27th, the mean reading for October amounting to 758.84 millimeters (29.875 inches), so that on the 27th the barometer stood above the normal.

Plate LI.





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With only a superficial inspection of the movements of the barometrical column it was, therefore, impossible to recognize the close proximity of the cyclone which a few hours later, on the 28th, desolated the Provinces of Batangas and Cavite and made itself so powerfully felt at the capital. If we, however, carefully consider the qualities of the fall, which commenced on the 27th, it will not be difficult to discern in it a warning, if not definitive at least sufficient to corroborate the other indications and to caution the observer that there is an atmospheric disturbance in the neighborhood. Indeed, if we compare the hourly barometric readings of the 27th with those of the 28th, we shall find that the three phases of the barometric fall plainly appear in the differences.

If we carefully examine the preceding table we shall notice the following points:

(1) The barometer fell constantly but slowly, as is seen by the differences between the hourly observations of the 26th and 27th. This constitutes the slow fall.

(2) The variation increased very much from the afternoon of the 27th until the occurrence of the absolute minimum at midnight on the 28th. Hence the study of barometric differences presents us with excellent means for the discovery of atmospheric disturbances.

(3) On the afternoon of the 27th, and still more on the 28th, the daily course of the curve changed very much. The daily minimum which comes on between 3 and 4 o'clock in the afternoon occurred on the 27th at 5 p. m. and on the 28th did not appear before 7 p. m. The nocturnal minimum, which occurs from 3 to 4 in the morning, was delayed until 6 a. m. on the 28th and until 10 a. m. on the 29th. The amplitude of the variation for the morning fell to 0.17 millimeters (0.007 inch), and it also remained very small during the afternoon of the same day. Consequently during the descent of the barometer the curve was considerably deformed, an unmistakable sign of great atmospheric changes. The present is another instance of the second partial change discussed in Part I.

(4) The two other phases of the fall of the barometer are also clearly shown by the barometric curve. The marked descent commenced at 3 a. m. of the 28th, hence twenty-one hours before the absolute minimum, and lasted until the beginning of the rapid fall at 11 a. m. of the same day. During the marked fall the amplitude of the barometric oscillation was notably reduced and during the rapid fall its effect disappeared entirely, as can be seen by a glance at the curve.

(5) The barometric curve corresponding to the posterior semicircle is extremely steep.

Wind.—The prevailing direction of the wind was northeast on the 27th, no sea breeze, a circumstance well worth noting. On the 28th the wind gradually drew to north and north-northwest. This in conjunction with the barometrical fall was a sure sign that a cyclone was approaching the place. The fact that the north-northwest wind lasted for fifteen hours, without any further western inclination being noticeable is a peculiar characteristic of the winds which precede cyclones that pass by to the south.

Since, as already stated, the lower clouds moved with constancy and considerable swiftness from northeast to southwest, it is easily understood how an experienced observer could for several hours in advance be sure of two things: First, that the center would pass close by his station, because neither wind nor clouds changed their directions; and secondly, that the center would pass him on the south side, since wind and clouds did not incline toward the fourth quadrant. We consider the direction of the clouds to be a very important element in order to find the position and the direction of the cyclone center, because they are not exposed to the deviation which the wind very often suffers in consequence of local obstacles.

We add to this cyclone a second one which passed very close to the place of observation.

THE CYCLONE OF JUNE 5 AND 6, 1896 (PLATE LI).

Classification.—This typhoon belongs to those of the ninth type and crossed twice the meridian of Manila.

First indications.—On the 4th at noon a distinct halo round the sun was noticed at the Manila Observatory, and in an easterly direction convergent cirrus streaks. The convergence lasted during the afternoon and the following morning, when the alto-cumuli also showed the same convergence for several hours. On the eastern coasts the weather was threatening, although the barometer showed no reasons for anxiety. On the contrary, it rose on the 3d, remaining comparatively high also on the 4th and 5th. It is true that the rise was very irregular, and several stations in Luzon reported a barometer rather unsteady. The prevailing winds also gave but little feeling of security, especially in the southern part of the island, where the winds on the 4th and 5th were almost constantly coming from the first quadrant. The Observatory published the following weather notice:

> **Barometer not very steady; the state of the clouds and the prevailing winds over the island point to the passage of a depression of small diameter in the south of the Archipelago. Prevailing direction of the wind east; rain in the south; thunderstorms in the northern quadrants.**

That these apprehensions were not unfounded very soon appeared. Already on the 5th a fall of the barometer occurred at the stations at Tayabas, Atimonan, Daet, Tabaco, and Albay, and at the same time the winds from north and northeast kept steady; this showed the approach of a cyclone in the south of Albay. In Calbayog the barometer also fell, and this to 753.30 millimeters (29.658 inches), lower than in Albay. The wind which had blown there at 3 p. m. on the 5th very strongly from northwest backed round to the west and southwest, and at the stations of the Visayas and the north of Mindanao it came almost from the same point. These observations show that the cyclone reached the Archipelago between the stations Albay and Calbayog, approaching, as it traversed the Straits of San Bernardino, somewhat closer to the latter town.

The notice published by the Observatory on the 6th ran as follows:

> **Barometer shows a decided fall; there is evidence that the depression announced yesterday has strongly developed; the postion of the center threatens to be dangerous to the southern part of Luzon and accordingly to Manila also. According to observations from Tayabas the center has fortunately turned more toward the west; it will, therefore, apparently pass at a greater distance from Manila than was feared. The squally northerly winds will therefore gradually draw round to northeast, east, and southeast, unless a change in the direction takes place, which will eventually be announced.**

OBSERVATIONS DURING THE CYCLONE OF JUNE 5 AND 6, 1896.

Date.		Barometer.	Thermometer (Celsius).	Relative humidity.	Wind.		Lower clouds.			Rain.	Remarks.
Day.	Hour.				Direction.	Force, 1-12.	Amount, 0-10.	Form.	Direction.		
				Per ct.						*Mm.*	
June 5	9.00 p. m.	758.70	26.4	94.0	Calm.	------	10	Cu.-N., S.	------	2.0	Completely clouded; rain.
	10.00 p. m.	57.92	25.8	95.0	ESE.	1	10	------	------	3.6	Completely clouded; lightning in SE.
	11.00 p. m.	57.52	25.8	94.0	ENE.	1	10	------	------	0.4	Completely clouded.
	Midnight	57.01	25.7	95.0	Calm.	------	10	------	------	1.4	Do.
June 6	1.00 a. m.	56.34	25.3	95.0	N.	1	9	------	------	2.4	Rain; horizon covered; slightly clearing in zenith.
	2.00 a. m.	56.16	25.2	95.0	N.	1	9	------	------	------	Do.
	3.00 a. m.	55.49	25.1	94.0	WNW.	2	10	------	------	0.6	Rain; horizon covered.
	4.00 a. m.	55.67	25.8	92.0	NW.	3	10	------	------	------	Light rain; slightly clearing in first quadrant.
	5.00 a. m.	55.15	24.7	95.0	NNW.	2	9	Cu.-N., S.	NE.	------	Light rain; rain in third and fourth quadrants.
	6.00 a. m.	55.09	24.4	96.0	NNW.	4	10	Cu.-N., S.	NE. by E.	0.5	Gusts at intervals; rain in fourth quadrant.
	7.00 a. m.	55.18	25.0	94.0	N.	2	10	Cu.-N., S.	NE. by E.	1.2	Some rain in ENE.; 7.10 a. m. light local rain.
	8.00 a. m.	55.18	25.5	93.0	NNW.	2	10	N.	------	------	Very heavy clouds in fourth quadrant; rain in first quadrant; 8.13 a. m. rain.
	9.00 a. m.	54.71	25.3	96.0	NNW.	3	10	N.	NNW.	------	Rain.
	10.00 a. m.	54.56	25.1	99.0	NNW.	3	10	N.	NNW.	1.2	Rain; intermediate clouds from E. by NE.?
	11.00 a. m.	54.16	25.3	98.0	NNW.	2	10	N.	ESE.	4.1	Light rain; intermediate clouds with great velocity from E.
	Noon	53.75	25.6	97.0	N.	3	10	Cu.-N., N.	ESE.	3.2	Light rain; 12.6 wind veers to NNE.; velocity 6 meters per second.
	1.00 p. m.	52.70	26.2	94.0	NE.	2	10	------	------	0.4	Rain in second and third quadrants; rain and wind squalls from ENE., 13 to 15 meters per second.
	2.00 p. m.	52.27	25.6	92.0	ENE.	5	10	N.	SE.	1.4	Wind squalls from ENE. and E. by NE., 15 to 17 meters per second; rain in all quadrants, especially in second and third.
	3.00 p. m.	51.65	25.8	89.0	E.	6	10	N.	------	------	Rain and wind squalls from E. and E. by NE., 23 to 25 meters per second; rain in second and third quadrants.

OBSERVATIONS DURING THE CYCLONE OF JUNE 5 AND 6, 1896—Continued.

Date.		Barometer.	Thermometer (Celsius).	Relative humidity.	Wind.		Lower clouds.			Rain.	Remarks.
Day.	Hour.				Direction.	Force, 1-12.	Amount, 0-10.	Form.	Direction.		
				Per ct.						*Mm.*	
June 6	4.00 p. m.	751.82	25.2	93.0	E.	5	10	N.	SE. by S.	4.6	Rain; frequent but short rain and wind squalls from E., 22 meters per second.
	5.00 p. m.	52.34	25.1	94.0	ESE.	3	10	N.	------	------	Rain.
	6.00 p. m.	53.93	25.0	99.0	SE. by E.	2	10	N.	------	16.0	Constant rain with gusts from ESE., velocity 9 to 12 meters per second.
	7.00 p. m.	54.97	24.9	99.0	SSE.	6	10	N.	SSE.	------	Rain; gusts from SSE. 17 to 19 meters per second; 7.53 rain abates.
	8.00 p. m.	56.35	24.6	98.0	SSE.	3	10	N.	SSE.	12.7	Rain, violent after 8.
	9.00 p. m.	57.39	24.2	97.0	S.	3	10	N.	------	------	Rain.
	10.00 p. m.	57.94	24.2	98.0	S.	3	10	N.	------	------	Do.
	11 00 p. m.	58.40	24.1	98.0	S.	2	10	N.	------	10.0	
	Midnight.	58.10	24.1	98.0	SSE.	2	------	------	------	------	
June 7	1.00 a. m.	58.00	24.3	97.0	S.	1	------	------	------	------	
	2.00 a. m.	57.90	24.5	96.0	SSW.	2	------	------	------	------	
	3.00 a. m.	57.55	24.6	94.0	SSW.	1	------	------	------	------	
	4.00 a. m.	57.70	24.0	96.0	SSE.	1	------	------	------	------	
	5.00 a. m.	58.04	23.4	97.0	ESE.	1	10	Cu.-N., S.	------	------	
	6.00 a. m.	58.65	24.2	93.0	Calm.	------	2	S.-Cu.	------	------	

Clouds.—The clouds evinced a tendency to veer to the east, coming constantly from the first quadrant, with the exception of a few very low ones which followed the direction of the wind, north-northwest. Within a few hours the change from northeast to south-southeast was effected. This was a sign of the great velocity and small size of the cyclone nucleus, which were the cause of the great destruction wrought in the inland seas. The more rapid the veering of the clouds to east takes place the more certain it is that the center will pass to the south of the place.

Barometer.—In this instance the slow fall of the barometer was not noticeable as soon as in the preceding cyclones; it first came on from midnight on the 4th to 9 p. m. on the 5th. The decisive fall with the second kind of partial change lasted till 4 a. m. on the 6th, and the rapid fall till the absolute minimum was reached at 3 p. m. on the 6th. The fall did not correspond to a cyclone passing very close, but the typhoons passing to the south do not lower the barometer so much, because their diameter is usually smaller than that of those passing to the north. This is also the reason why the zone of destruction of this storm had but a small width.

Rain.—Not only the zone of the rapid fall but zone B already were characterized, especially on their front side, by large quantities of rain.

Wind.—The winds were not steady, nor did they clearly exhibit their cyclonic character until shortly before the beginning of the decided fall, another indication of the limited extent of the cyclonic nucleus. The veering over east toward south was, however, rapid and quite according to the laws mentioned in Chapter IV of Part II.

CHAPTER V. CYCLONES WHICH PASS BY NEAR OR FAR TO THE SOUTH.

We shall content ourselves with describing the general characteristics of typhoons which pass at a distance, greater or less, south of a place without first giving typical instances of such storms. When speaking in Chapter VII of the Philippine cyclones properly so called, it will be noticed that every one of these, when on the first branch of its parabolic trajectory, necessarily passes the meridian of Manila south of the city. Hence the examples discussed there may also serve to illustrate what we have to say in the present chapter.

Clouds.—The higher clouds usually come from the second quadrant, fairly near the south, a day or two before the distant cyclone crosses the meridian of the place of observation. Thus, for instance, the day before the famous "Gravina typhoon" of melancholy memory crossed the Visayas on May 9, 1895, the cirri were observed to come from southeast, the point in which the cyclonic vortex lay. On other occasions feathery cirri, well formed and with persistent convergence toward the southern quadrants, are seen. We even remember cases in which, without any noticeable alteration of the other meteorological elements, the sole convergence and movement of the cirri revealed to us at Manila the existence and progress of a perturbation which traversed the southernmost part of our Archipelago. An example of this kind was the typhoon of May, 1894.

The lower clouds come in the beginning from a northerly direction, and later, as the cyclone which is to pass by to the south draws sufficiently near to accentuate the descent of the barometer but before it crosses the meridian, they come from the first quadrant. The more rapidly this shift takes place, without, however, going as far as east and before the decisive fall of the barometer has commenced, the greater is the probability that the center will pass by at a great distance to the southward.

Here is generally a notable difference in the direction of the clouds when a cyclone passes at a distance to the south and when it passes close. If the center is to pass far to the south, the lower clouds usually come for some hours steadily from east-northeast, without the fall of the barometer assuming the decisive stage. If the center will pass nearer to the south, the clouds will likewise come from east-northeast, but at the same time the barometer shows a decisive fall. An example for the first case is the Gravina typhoon;[1] for the second, the typhoon of Samar and Leyte, which has become notorious owing to the destruction which it wrought (October 12 and 13, 1897).[2]

Rain.—The amount of rain depends very much on the direction of the wind squalls, whether they are favorable for the condensation of the vapor or not. The direction of the rain squalls may at the first be valuable for fixing the position of the center; and if the wind comes, for instance, from the north, drawing round to the first quadrant during the rain squalls, it may be taken as a sign that the center will pass to the southward, as we could prove by many practical instances.

Barometer.—If the barometer was normal or high for a few days, then on the approach of the cyclone a gradual fall commences, sometimes two or three days before the meridian is crossed. This fall, as we have repeatedly remarked, is a valuable indication and at least should be taken as a warning. In Manila the fall is usually not so great as when a cyclone approaches on the north side. We have not been able to ascertain whether the same occurs also at all other places in the Archipelago. At any rate, it may be said that if the daily variation does not disappear the place will not come to lie farther in than zone A. If the alteration is rather considerable the place may come into zone B—that is, the cyclone may pass by close—especially if we consider that for Manila and the greater part of Luzon the barometer has, as already said, a less tendency to fall.

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[1] "Baguio del Gravina." Manila, 1895.

[2] "El Baguio de Samar y Leyte." Manila, 1898.

Wind.—About the wind we may say much the same as of the clouds. If a cyclone approaches in the south, the winds come from the first quadrant. The probability that we are feeling winds caused by a cyclone will be all the greater the more their direction deviates from the normal. The shift will be all the more rapid, the smaller the distance from the center; it is very slight and almost zero, as has been observed in Luzon when a cyclone is moving through the southernmost part of the Archipelago during the months of the first group. The shift, if it takes place, is always from north to east.

We once more repeat that at certain seasons certain places will not be touched by any cyclones passing by in the south. Such places are, for instance, Iloilo, during the months of the third group, and more certainly still the regions situated further south, accordingly the southern parts of the Islands Cebu, Panay, Negros, Bohol, Dinagat, Mindanao, Basilan, and the whole Jolo Archipelago.

CHAPTER VI. THE CYCLONE OF NOVEMBER 20 TO 22, 1892.

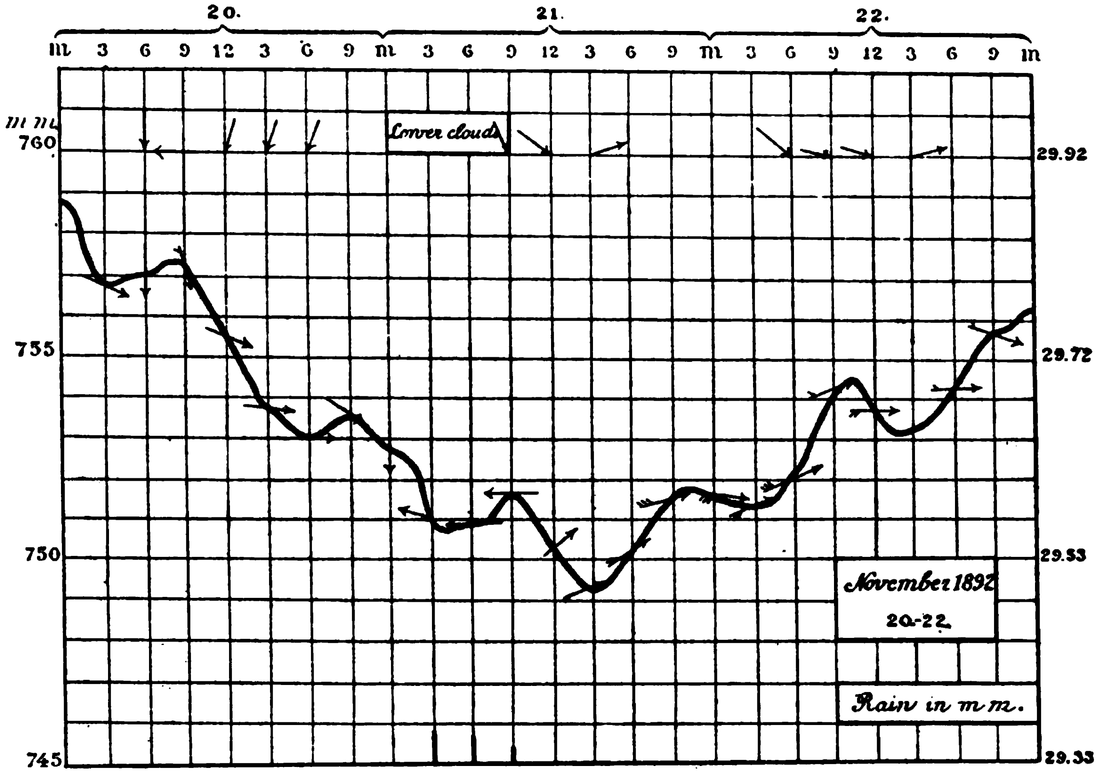
PLATE LII.

Classification.—We find a brief description of the trajectory of this cyclone in the appendix to the observations of 1892 published by the Observatory:

> From the 17th to the 25th of November, 1892, a deep depression crossed the Pacific Ocean. The place of its formation appears to have been outside of the Western Carolina Islands; its effects were felt at Agaña on the 17th and at Goreor during the night of the 18th and 19th; it then took a direction which was very threatening for the Island of Luzon, but fortunately it recurved on the 20th to the north, though it still exercised a strong influence upon the barometers in the southeast of the island. The depression passed close to Cape Engaño on the 22d, recurved to the north-northeast, and soon to the northeast, without notably slackening its speed, as is usually the case during recurvature. On the 23d the cyclone reached Japan, and crossed the whole south of the empire in less than twenty-four hours.

OBSERVATIONS MADE DURING THE CYCLONE OF NOVEMBER 20 TO 22, 1892.

Date.		Barometer.	Thermometer (Celsius).	Relative humidity.	Wind.		Lower clouds.			Rain.	Remarks.
Day.	Hour.				Direction.	Force, 1-12.	Amount, 0-10.	Form.	Direction.		
				Perct.						*Mm.*	
Nov. 20	8.00 p.m.	753.57	27.6	73.0	NW.	3	10	S.-Cu.			Gusts of 7 to 8 meters per second velocity.
	9.00 p.m.	53.50	27.1	81.0	NW.	2	10	Cu.-N.			Rain clouds.
	10.00 p.m.	53.13	26.0	82.0	WNW.	1	10	S-Cu., N.			Heavy clouds in ENE., E., ESE., and SE.
	11.00 p.m.	52.80	25.6	86.0	N.	1	10				Clouds seem to come from N.
	Midnight.	52.56	25.1	90.0	N.	1	10	N.			Rain; heavy waves in bay.
Nov. 21	1.00 a.m.	52.83	24.3	92.0	NE.	1	10	N.			Passing rain.
	2.00 a.m.	51.41	23.9	96.0	NNE.	1	10	N.			Rain.
	3.00 a.m.	50.81	23.9	95.0	ESE.	1	10	N.			Rain; heavy waves in bay.
	4.00 a.m.	50.61	23.6	97.0	NNE.	1	10	N.			Fine rain; heavy waves in bay.
	5.00 a.m.	50.76	23.7	96.0	Calm.		10	N.			Light rain.
	6.00 a.m.	50.91	23.7	97.0	NNE.	1	10	N.	NNW.		Light rain; clouds also from NW. and N.
	7.00 a.m.	51.00	23.6	97.0	NE. by N.	1	10	N.	NNW.		Light rain; sky covered part of third quadrant.
	8.00 a.m.	51.25	23.8	97.0	ENE.	1	9	N.	NNW.		Horizon covered, except toward third and fourth quadrants.
	9.00 a.m.	51.70	24.4	97.0	E.	1	9	N.	NW., NNW.		
	10.00 a.m.	51.19	25.2	97.0	E.	1	9	Cu.-N.	SW.		Horizon black, except third quadrant.
	11.00 a.m.	50.75	26.4	91.0	NNW.	2	9		NW.		
	Noon	50.22	27.7	86.0	SW. by W.	1	9		NW.		
	1.00 p.m.	49.55	28.2	81.0	Calm.		9		NW., SW.	0.1	
	2.00 p.m.	49.38	27.7	81.0	NNW.	1	9		SW.	0.8	Rain in whole first quadrant; local drizzle.
	3.00 p.m.	49.30	27.6	83.0	WSW.	1	10		WSW.	1.8	Black from NE. to SSE.; rain in fourth quadrant.
	4.00 p.m.	49.31	28.2	81.0	WSW.	2	10		W.	1.0	NW. to SSE. very dark; Cu.-N. seem orientated toward ESE.
	5.00 p.m.	49.76	28.2	78.0	WSW.	4	10		WSW.	0.3	Very dark in E.; Cu.-N. seem orientated toward ESE.
	6.00 p.m.	50.32	27.8	84.0	SW.	3	10			0.8	Horizon dark, especially in first quadrant.
	7.00 p.m.	50.77	28.1	79.0	WSW.	3	10			1.0	7.06 p.m. gusts; velocity, 11 meters per second.
	8.00 p.m.	51.30	28.1	77.0	W. by SW.	3	10	N.			
	9.00 p.m.	51.62	28.1	74.0	WSW.	5	9	S.-Cu.		0.3	Tempest in S.; slightly clearing in zenith; streaks of clouds convergent toward ESE.; gusts from third quadrant, 12 to 14 meters per second.
	10.00 p.m.	51.81	27.8	76.0	WSW.	4	9	S.-Cu.			Gusts 10 to 12 meters per second velocity.
	11.00 p.m.	51.81	27.7	76.0	W.	5	8				Gusts 13 to 15 meters per second velocity.
	Midnight.	51.71	27.7	76.0	W.	4	7				Gusts 10 to 12 meters per second velocity.
Nov. 22	1.00 a.m.	51.57	27.6	77.0	WSW.	4	4				Do.
	2.00 a.m.	51.47	27.5	76.0	WSW.	4	4				Do.
	3.00 a.m.	51.53	27.4	76.0	WSW.	4	3				Gusts 11 to 13 meters per second velocity.
	4.00 a.m.	51.38	27.3	76.0	WSW.	5	3				Gusts 12 to 13 meters per second velocity.
	5.00 a.m.	51.80	27.1	77.0	WSW.	4	3				Ci. orientated NNW. to ESE.
	6.00 a.m.	52.30	27.2	78.0	WSW.	4	3		NW.		Heavy clouds in first quadrant and part of second.
	7.00 a.m.	53.16	27.6	76.0	W. by SW.	2	4		WNW.		Arborescent Ci. in NNE.
	8.00 a.m.	53.91	27.7	77.0	W. by SW.	3	4		WNW.		An arch of Ci. whose center is in NNE.
	9.00 a.m.	54.39	28.3	76.0	W. by SW.	2	5		WNW.		Aborescent Ci. in NNE.
	10.00 a.m.	54.70	28.3	77.0	WSW.	2	7		WNW.		Heavy clouds toward first quadrant.


20.
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29.72
29.53
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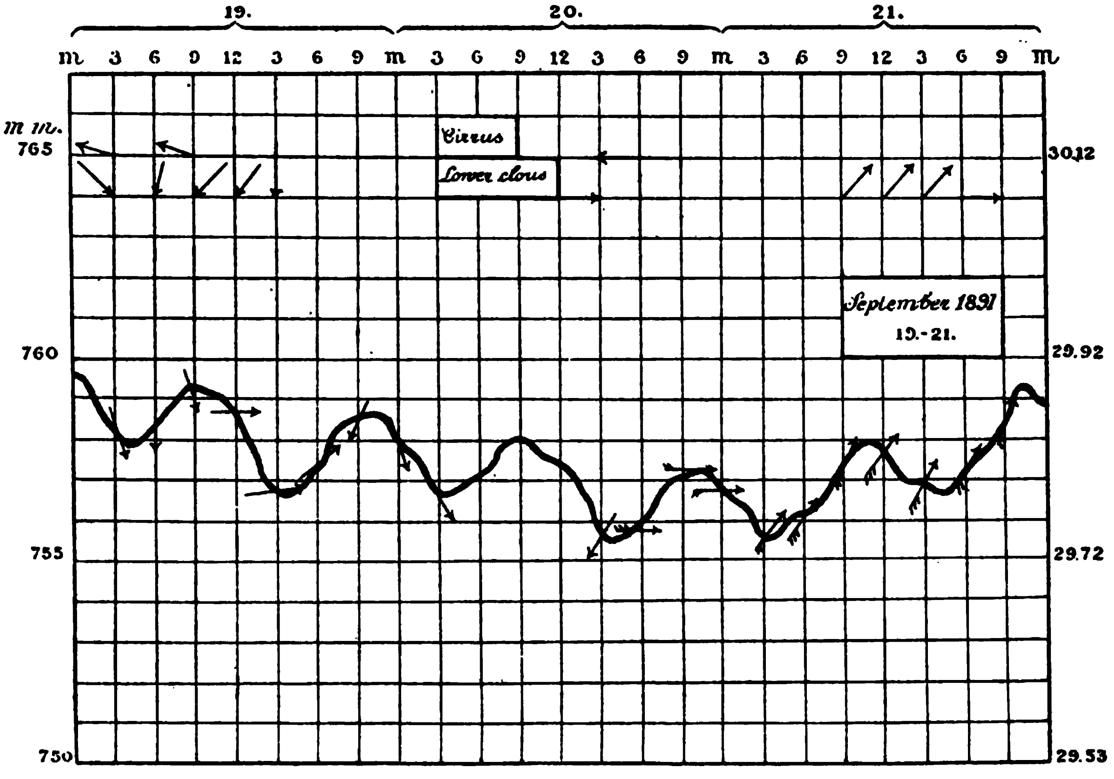
Lower clouds
November 1892
20-22.
Rain in m m.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Cirrus
Lower clous
September 1891
19.-21.

UNIV. OF MICH.

This cyclone belongs to those of the Pacific and Magellanes. The mean velocity was 12 nautical miles per hour. When cutting the latitude of Manila, the track had an inclination of W. 56° N.

Clouds.—On November 20, during the whole afternoon, the lower clouds came from north-northeast. On the morning of the 21st they had veered round to north-northwest and northwest, the barometer was falling, and the downward movement becoming more marked. At the time of the barometrical minimum in the afternoon the clouds showed an inclination toward west-southwest under the influence of the surface currents. Everything pointed to the fact that the center had approached Luzon and crossed the latitude of Manila to the east. The clouds took then again a west-northwest direction, coming from this point during almost the whole of the 22d, and at the same time the barometer rose again. These were convincing proofs that the center was recurving in the Pacific.

The observations of the higher clouds brought out valuable points: (1) The cirrus streaks were orientated from north-northwest to south-southeast as long as the center lay to the north-northeast of Manila, which confirms what we have said in Chapter I, Part II; (2) later on arborescent cirri made their appearance to the north-northeast, remaining for several hours. This, according to Chapter II, Part II, was an indication that the vortex lay in this direction from Manila. So it was indeed, for, after recurving with exceptional velocity, the typhoon followed for a long time a north-northeast direction.

Rain.—The quantity of rain was but small and fell almost exclusively with the winds from the third quadrant.

Barometer.—The movement of the barometer corresponded theoretically to that of a recurving cyclone. Although this time the recurvature occurred more rapidly than usual, the center, nevertheless, remained for some time at the same distance from Manila. This is probably the reason why the low barometer lasted such a long time. On the 21st the instrument remained almost during the whole day near 750 millimeters, and although the daily oscillation was not completely lost, the amplitude was very small. The slow fall was protracted, and of the decisive fall there were but slight indications noticeable, so that Manila can have scarcely entered into zone B.

Wind.—The winds which prevailed in Manila during this cyclone are well worthy of study. At the beginning the direction of the wind was changeable, on account of the upper currents not being steady. On the 20th the prevailing wind came from northwest, from a direction which corresponds to the approach of a center, and actually the cyclone was then approaching Luzon. In the afternoon of the same day the wind veered to north, drawing next to east-northeast and east; this stood undoubtedly in connection with the rain, which made the wind's direction less convergent. Although this shifting of the wind may be anomalous, the clouds kept nevertheless steady in their north-northwest direction. As the center recurved, the wind drew to the fourth quadrant and soon afterwards to the third, without the barometer falling any more. This confirms the rule: If the wind shifts from fourth to the third quadrant, the barometer being steady or rising, the center is recurving to the east of the observer. The upper and lower currents became more developed while the cyclone was passing along the second branch of its parabolical track.

CHAPTER VII. THE CYCLONE OF MAY 10 TO 19, 1896.

PLATE LIII.

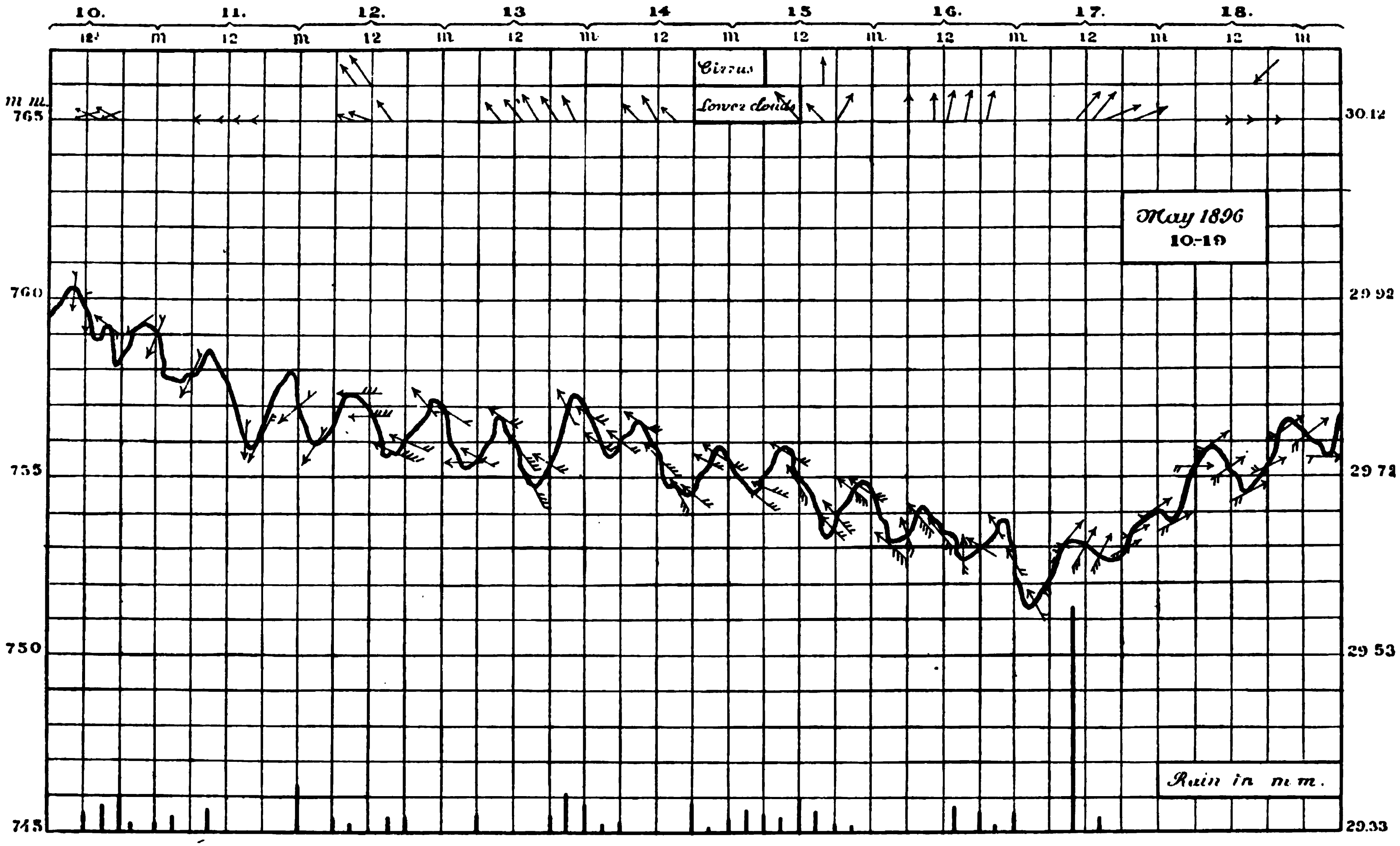
Classification.—We may call this cyclone the typhoon of Iloilo on account of its passing very close to the south of this place. For eight days it kept the population of Luzon in anxiety and in its track caused great destruction. In its appearance and progress it was typical, and it belonged to those of the Philippines in a strict sense, because of its influence being felt only in this group of islands. Its mean velocity when crossing the Visayas was 10 miles per hour; while it recurved in the China Sea its speed did not amount to more than 3 miles, but when it recrossed Luzon a mean velocity of 11 miles per hour was observed. The mean inclination of the track was very variable. In its first branch it was west-northwest; after recurving to the west of Manila it followed the direction of the first quadrant, having a considerable inclination to the north.

Observations.—Not being able to give the hourly observations for the whole nine days during which the storm was felt, we content ourselves with giving in the table three-hourly data, especially as we have graphically represented on Plate LIII the prinicipal meteorological elements.

OBSERVATIONS DURING CYCLONE OF MAY 10 TO 18, 1896.

Date.					Wind.		Clouds.						
Day.	Hour.	Barometer.	Thermometer (Celsius).	Relative humidity.	Direction.	Force, 1-12.	Amount, 0-10.	Higher.		Lower.		Rain.	Remarks.
								Form.	Direction.	Form.	Direction.		
				Perct.								Mm.	
May 10	6.00 a.m.	759.09	25.2	92.0	Calm.	------	6	------	------	Cu.-S.	------	------	
	Noon	59.55	28.9	79.0	N.	1	10	Ci.-S.	------	Cu.-S., N.	ENE.	0.5	Rain in first and fourth quadrants.
	6.00 p.m.	58.87	25.9	93.5	Calm.	------	10	Ci.-S.	------	Cu.-S., N.	ESE.	9.8	Intense blackness in third and part of second quadrant.
	Midnight	58.95	25.3	93.0	NNE.	1	------	------	------	------	------	0.7	
May 11	6.00 a.m.	58.01	25.1	90.0	NE.	1	10	------	------	Cu.-S., N.	------	0.8	
	Noon	57.70	28.6	85.0	Calm.	------	10	Ci.	------	Cu.-S., N.	------	2.0	Rain at various points on horizon.
	6.00 p.m.	56.17	28.2	80.0	NE.	2	10	Ci.	------	Cu.-S.	------	------	Do.
	Midnight	57.15	24.9	96.0	ENE.	1	------	------	------	------	------	7.0	
May 12	6.00 a.m.	56.56	24.9	99.0	Calm.	------	10	------	------	Cu.-S , N.	------	0.7	Rain; horizon black with rain.
	Noon	56.69	30.4	72.0	E.	3	9	Ci.-Cu.	SE.	Cu.-S., N.	ESE.	0.6	Gusty wind, rain in S., SSW., and SW.
	6.00 p.m.	56.21	25.9	94.0	ESE.	1	10	------	------	N.	------	3.6	Light rain; sky dark, especially in third and fourth quadrants and S.
	Midnight	56.65	25.8	94.0	ESE.	1	9	------	------	N.	------	------	Zenith clears; lightning in E.
May 13	6.00 a.m.	55.51	25.5	93.0	ESE.	1	10	------	------	Cu.-S., N.	------	1.8	
	Noon	55.78	28.3	90.0	SE.	2	10	------	------	Cu.-S., N.	SSE.	------	
	6.00 p.m.	55.56	25.2	92.5	ESE.	1	10	------	------	N.	S., SSE.	1.6	Light rain; rain in third and fourth quadrants.
	Midnight	56.76	24.4	95.0	ESE.	1	10	------	------	N.	------	10.1	Local rain.
May 14	6.00 a.m.	56.00	24.8	92.0	ESE.	2	10	------	------	Cu.-S., N.	------	1.7	Fine rain; first quadrant full of rain.
	Noon	55.51	28.3	75.0	SE.	3	10	A.-Cu.	S.	Cu.-S.	SSE.	------	Intense darkness in third quadrant.
	6.00 p.m.	54.37	25.6	90.0	ESE.	1	10	------	------	N.	------	4.3	Light rain.
	Midnight	55.37	25.3	94.0	SE.	2	10	------	------	N.	------	1.5	Local rain.
May 15	6.00 a.m.	54.72	24.8	96.0	ESE.	2	10	------	------	Cu.-S., N.	SSE.	5.1	Rain; horizon dark with rain in second and fourth quadrants.
	Noon	54.57	26.5	89.0	SSE.	2	10	------	------	N.	SE.	6.5	Light rain; low clouds from S. and still lower from SE.
	6.00 p.m.	53.75	26.2	87.0	SE.	3	10	Ci.-S.	------	Cu.-N.	SSW.	2.8	Wind gusty; squalls from second quadrant.
	Midnight	54.37	27.4	75.0	SE.	3	10	------	------	N.	------	0.2	Very violent gusts at intervals; light rain.

Plate LIII.



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OBSERVATIONS DURING CYCLONE OF MAY 10 TO 18, 1896—Continued.

Date.					Wind.		Clouds.						
								Higher.		Lower.			
Day.	Hour.	Barometer.	Thermometer (Celsius).	Relative humidity.	Direction.	Force, 1-12.	Amount, 0-10.	Form.	Direction.	Form.	Direction.	Rain.	Remarks.
				Per ct.								Mm.	
May 16	6.00 a.m.	753.40	27.3	83.0	SSE.	4	10	----------	------	Cu.-S., N.	S.	------	Fourth quadrant and part of first black with rain.
	Noon	53.41	28.8	82.0	SE. by S.	5	10	----------	------	Cu.-S., N.	SSW.	------	Rain in third and fourth quadrants.
	6.00 p.m.	52.97	25.6	93.0	ESE.	1	10	----------	------	Cu.-S., N.	SSW.	4.5	Rain in SSW. and fourth quadrant.
	Midnight	52.50	25.5	93.0	SSE.	3	------	----------	------	----------	----------	2.2	
May 17	6.00 a.m.	52.10	25.3	97.0	SSW.	8	10	----------	------	N.	----------	------	
	Noon	52.95	27.8	84.0	SSW.	4	10	Ci.-S.	------	Cu.-S., N.	SW.	34.5	Strong squalls from fourth and part of first quadrant.
	6.00 p.m.	52.86	26.7	88.0	WSW.	5	10	----------	------	Cu.-S., N.	WSW.	1.9	Strong squalls from first, third, and fourth quadrants; wind veers to W.
	Midnight	53.95	26.7	88.0	WSW.	4	------	----------	------	----------	----------	------	
May 18	6.00 a.m.	55.22	26.6	83.0	W.	3	10	----------	------	Cu.-S., N.	----------	------	Rain in second quadrant.
	Noon	55.22	28.0	85.0	WSW.	3	10	Ci.-S.	------	Cu.-S., N.	W.	------	Squally toward W.
	6.00 p.m.	55.24	26.9	90.0	WSW.	3	4	Ci.-S.	NE.	Cu.-S.	----------	------	Tufts of Ci.-S. convergent toward NNE.

The first indications.—The electrical phenomena have already been discussed (Part II, Chapter IX., p. 182). During the first hours of the morning on the 11th cirro-cumuli which came from east-southeast were noticed, the center then being to the south by east of Manila; a second indication was the gradual fall of the barometer, which commenced at noon on the 10th.

In order to give a better view of the various meteorological elements we shall divide the cyclone into three sections which follow each other naturally: (1) The first branch of the parabolic track, corresponding in the phenomena which were observed at Manila to those of a cyclone passing to the south; (2) the recurvature showing the characteristics of a cyclone recurving to the westward; (3) the second branch, which for Manila has the characteristics of a cyclone crossing the meridian to the north but is moving from west to east.

The first branch—Clouds.—During almost the whole morning of the 10th the lower clouds came steadily from east-northeast, the barometer falling slowly. In the afternoon the nimbi had the direction east-southeast, but on the 11th the cumuli came still from east, while the barometer kept on falling slowly; the center crossed, therefore, far to the south. On the morning of the 12th the direction of the clouds was east-southeast, in the afternoon southeast. This direction still lasted early on the 13th but in the afternoon it had shifted to the south-southeast; at noon the center had not yet crossed the latitude of Manila to the west.

Rain.—During this first section rain fell almost incessantly, but it was not very heavy, the greater part falling with easterly winds.

Barometer.—The movement of the barometer during the first branch of the typhoon is very noteworthy. On the 11th the barometrical curve showed, after a slow fall, a partial minimum, to rise again slightly on the 12th. The explanation of this is that when crossing the meridian of Manila by the south on the 11th, the storm was at its minimum distance from the capital on this side, receding somewhat from it as it entered into the China Sea. When the cyclone commenced to recurve on the 13th, the barometer fell anew, but always very slowly.

Wind.—As in the first branch the distance was always greater than 200 miles, the surface currents could not become fully developed. In the beginning the prevailing winds were north; next they came from the first quadrant, having a tendency to draw round to the east; on the afternoon of the 12th they came with east-southeast from the second quadrant. Early on the 13th the wind came from southeast, going round to south, from which fact, with the renewed fall of the barometer, it might be concluded that the center was about to recurve.

The recurvature—Clouds.—From the 13th until the 15th, for the space of more than two days, the clouds came constantly from south by southeast and then followed the slow descent of the barometer. It was, therefore, certain that the typhoon recurved in the China Sea, Manila being for about three days at the same distance from the center. On the 15th the cloud direction inclined toward south and south-southwest, the vortex most probably crossing our parallel of latitude by the west on this day.

Rain.—Also during this second period of the cyclone it rained continually, but not heavily.

Barometer.—As the currents on the earth's surface veered round to south and south-southwest, the barometer fell slowly, reaching its absolute minimum when the clouds were already coming from the third quadrant and the wind blew from south-southeast and south early in the morning of the 17th. The daily range and the slow fall were still observed, so that Manila remained in zone A.

Wind.—The wind's direction (southeast, shifting somewhat to south-southeast) kept steady from the afternoon of the 13th until noon on the 16th, while the center was recurving very slowly.

The second branch—Clouds.—During the afternoon of the 16th the clouds came already from the third quadrant, veering slowly to west as the center was about to reënter the Archipelago on the second branch of its trajectory. This is an excellent example in confirmation of the law of cyclonic circulation, which becomes all the more valuable, because convergent cirrus streaks appeared in the northeast on the 18th, leaving no doubt as to the position of the center. The cirri and lower clouds crossed each other at an angle of about 12°, which again corresponds to what we have already said with regard to the convergence of the lower clouds in the rear of a cyclone.

Rain.—The quantity of rain which fell at Manila while the lower currents came steadily from the third quadrant is of special interest, since it confirms in all its entirety what has been said about local influence.

Barometer.—On account of the greater inclination of the track toward north, the barometer rose quicker than it had fallen. The variation early in the morning on the 18th could only have a small amplitude, because the rise was considerable and partly balanced the normal fall at this time.

Wind.—On account of the center passing to the north of Manila, early on the 18th the winds kept a westerly direction. They had gone round three quadrants of the compass. The center had traveled from southeast over south and west to northeast, and consequently the winds were bound to change from north to west, "backing" through east and south.

Remarks.—We do not speak here of any special phenomena observed during this typhoon, as it does not belong to Part III. We only record what we said when we made a study of this cyclone of the Philippines.

> Considering all the circumstances, this typhoon appears to be a typical one in all its principal characteristics and confirms many laws of great practical importance such as: The axis of the cyclone may have an inclination toward different directions at different places, as was the case at Tacloban and Iloilo. The winds of the same cyclone are in a different degree convergent, and the more so in the rear than in the front. In the body of the cyclone thunderstorms (strictly speaking) do not appear, while they are very common on its outer borders. Finally, a diligent observation of the direction of the wind and the fall of the barometer are of excellent service in order to ascertain the position of the center.

The "Philippine cyclones" are not so rare as they appear to be. In 1895 occurred the sadly famous "Gravina typhoon," and we are of opinion that some storms which we find recorded in the old chronicles were cyclones of this class. They are described as having caused destruction in the China Sea in front of Manila, raging during many days, like the one just discussed, likewise in the month of May. We will cite only one instance:[1]

> On the 29th of May of the year 1654 there entered these Islands Father Juan de Montiel, cast ashore by the shipwreck which the *Galeón* suffered when already near the port (Manila); and for more than fifteen days, during which the fury of the storm rendered assistance impossible, he suffered from hunger and want of clothing, without the severe inclemency of the weather ever abating. But God preserved him for future labors by which to merit the crown of eternal bliss.

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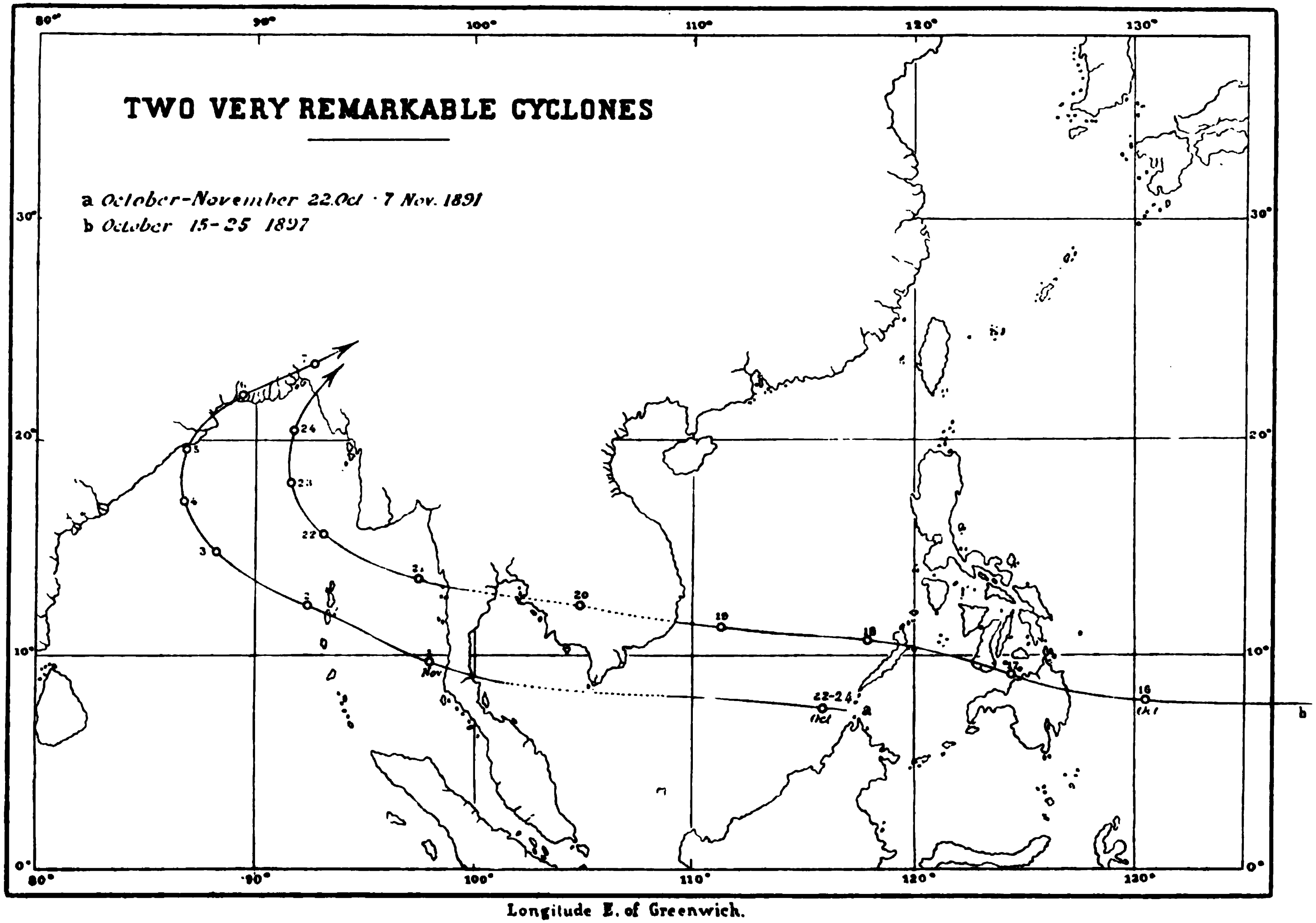
[1] "Historia de Mindanao y Joló," by Fr. Francisco Combés, S. J. Madrid, 1667 (reprinted, 1897), column 566.

Plate LIV.


TWO VERY REMARKABLE CYCLONES
a October-November 22.Oct · 7 Nov. 1891
b October 15-25 1897
80°
90°
100°
110°
120°
130°
30°
20°
10°
0°
24
23
22
21
20
19
18
16
Oct
22-24
Oct
5
4
3
2
Nov
a
b
Longitude E. of Greenwich.

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CHAPTER VIII. TWO REMARKABLE TYPHOONS.

I. THE PORT BLAIR CYCLONE, OCTOBER 22 TO NOVEMBER 7, 1891.

In Chapter IV of "Handbook of Cyclonic Storms in the Bay of Bengal" Mr. Eliot describes in a masterly manner eight typical cyclones, two of which were first felt in the Philippines. The first was formed to the west of Paragua on October 22, 1891, and by the first week of November it had run through the Bay of Bengal on its path of destruction, and on account of the damage done by it was known as the "Port Blair cyclone."

Origin of the storm.—Mr. Eliot says:

> The circumstances attending the origin of the storm have not been determined in the absence of information. The storm is known to have crossed the Gulf of Siam on the 30th and 31st of October. The director of the Hongkong Observatory states that no bad weather was reported in the China Sea from the 23d of September to the 12th of November. He also adds that he has come across only one case of a small cyclone which originated in the Gulf of Siam and advanced westwards, probably across the Malayan Peninsula.

The cyclone in the Archipelago.—In the meteorological review of the Bulletin of the Manila Observatory for October, 1891, we find the following paragraph:

> The meteorological curves register another minimum which was accentuated on the 22d in the south stations and in north stations on the 23d. This seems to indicate the influence of a distant center which is gaining in latitude (or increasing in intensity) and whose movements affect our barometers. We would not call attention to this if we rested solely on the difference of pressure in Manila or even in the Archipelago; but the circumstances of the direction of the wind on the above days showed that there was a center of attraction to the west of Paragua, and the currents experienced by the vessels sailing in the China Sea confirmed this. Very probably the typhoon which was felt on the 30th and the 31st in Singora and other cities, then traversed the Peninsula of Malaca after running through the Gulf of Siam, to obtain new strength in the Bay of Bengal, was formed in this region.[1]

The barometers began to fall in the meteorological stations of Luzon on the 21st. The minimum was registered in Albay, the most easterly station, on the 22d, and at Cape Bolinao, the most westerly station, on the 23d. The dominating winds in the western stations of the south of Luzon were from the east, which was an indication of a center of low pressure toward the southwest of Luzon or in the Jolo Sea or else toward the south of Paragua during the 21st, 22d, and 23d. In the light-house of Cabra Island pressure was low from the 22d to the 25th. The vessels that during this time were in the China Sea not far from the coasts of Luzon and Mindoro encountered winds from the northeast and east, with barometers somewhat low. The steamship *Don Juan,* on leaving Hongkong on the 24th, encountered strong winds from east-northeast, which can scarcely be explained satisfactorily unless there was a center of low pressure to the south or south-southwest of that colony. On the other hand, if we examine the observations of Hongkong we find that the lowest mean pressures were registered from the 22d to the 28th, and that the wind from east by southeast attained its greatest force during this time. The steamship *Herminia* in her voyage from Amoy to Manila met winds from east, east-southeast, and southeast from the 26th to the 28th, so that the center of depression had moved slowly, as the observations show, till on the 28th it was probably in the Gulf of Siam. This is deduced from the observations made on board some of the vessels which were crossing the China Sea from October 22 to 28. The English steamship *Mongkut* left Bankok on the 16th and arrived in Hongkong on the 25th. From Pulo-Obi to Cape Padaran, which she passed on the 20th or the 21st, she met nasty weather, and at Cape Padaran fresh winds from north-northwest and north-northeast with squalls and a swell till she reached the Ladron Islands, where she experienced strong winds from east-northeast and a heavy sea from northeast.

The steamship *Zafiro* sailed from Manila on the 23d and met variable winds from north-northeast to southeast which were accompanied by rain and cross seas.

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[1] "Bolletin Mensual de Octubre, 1891."

The English steamship *Palimurus* left Singapore on October 25, with variable winds from the northeast which continued as far as Paracels, where she found strong winds from the northeast with squalls, which seemed to indicate that the center of depression was almost stationary in the beginning and that on the 28th it was not far from the meridian of Paracels in its approach to the Gulf of Siam.

Further history of the cyclone.—The work of Mr. Eliot concerning these storms is so instructive for the thorough understanding of the mechanism of cyclones that it will not be without advantage if we insert here a few paragraphs, all of which can be applied to the typhoons of the Far East generally. Mr. Eliot says:[1]

According to the few reports of the storm received from Siam the cyclone was fully developed on the 30th and advanced over the Gulf of Siam along a westerly course on the 30th and 31st. The storm passed over the Island of Koh Samuie on the evening of the 31st, when the steamship *Rainbow* capsized near that island and the officers and crew of 30 men and 3 passengers with the exception of 6 natives were all lost.

The storm crossed the Malayan Peninsula during the night of the 31st and almost completely wrecked the towns of Bandon and Chaiya, the latter being one of the largest towns on the Gulf of Siam. The storm broke out at Chaiya at 11 p. m. of the 31st and lasted until 3 a. m. of November 1. A storm wave flooded the town to the depth of 7 or 8 feet. Three hundred and eighty-seven religious buildings and 4,238 other buildings were more or less completely destroyed and 109 people died by drowning or by falling houses, etc. At Renong, on the west side of the peninsula, the storm lasted from about 1 a. m. to 7 a. m. of the 1st. The destructive part of the storm area averaged about 60 miles in breadth. The severity of the storm in this belt was very great, as houses, trees, etc., were all leveled to the ground and the roads rendered impassable by the rains and fallen trees.

The storm at this stage advanced at an average rate of about 18 miles per hour and passed out into the Andaman Sea early on the morning of November 1. It was of comparatively small extent, the inner area of hurricane winds not exceeding 80 miles in its longest diameter and 60 miles in its shortest diameter at right angles to the direction of motion.

It advanced over St. Mathew's Island in latitude 10° N. and longitude 98½° E. on the morning of the 1st. Large trees were uprooted by the storm and the foliage either stripped from the trees or blackened as if scorched by fire.

The following is a brief history of the progress of the storm in the Andaman Sea and Bay of Bengal:

November 1.—Pressure was very considerably above the normal on the 31st of October, but was beginning to give way over nearly the whole of India. The changes were, however, small, and the pressure distribution in the Indian land area on the morning of the 1st of November was similar to that of October 31. The chief features were:

(1) Pressure was in excess over the whole of India by amounts averaging very nearly a tenth of an inch.

(2) Pressure was most largely in excess in the area stretching from the South Deccan and Circars to Bihar and the northwestern provinces. That area was hence one of local excess of pressure.

(3) The excess of pressure was least in amount in Lower Burma and the south of the bay and off the Malabar coast. The cyclone was entering this area of local deficiency of pressure in the Andaman Sea, and was hence intensifying the deficiency. * * *

November 2.—The decrease of pressure which had commenced on the 31st continued on the 1st. The changes were small and less than .05" except in the greater part of the bay and the adjacent coasts (except Tenasserim).

Skies were clear and weather fine over the whole of India except in Lower Burma and Southern India, where they were heavily clouded. The peninsula south of latitude 15° N. had received general light to moderate rain during the previous twenty-four hours.

The cyclone passed over Port Blair between 2 and 3 a. m. of the 2d and then crossed out from the Andaman Sea into the Bay of Bengal. Assuming that its direction and rate were the same on the morning of the 2d as on the 1st, a supposition which is confirmed by the marine data, the center at 8 a. m. would be in latitude 12° 10′ N. and longitude 91° 10′ E.

The following is Mr. Carroll's account of the storm:

"On the afternoon of the 1st instant, at about 2 p. m., rain clouds, banking up from the east and northeast, soon overspread the sky and burst, attended by strong wind. After a good shower, registering 0.60 inch of rain, the wind abated, leaving the usual gloomy state of weather experienced on a monsoon day. During this shower I noticed that there was some disturbance in the upper currents of air; for, the lower clouds—though moving chiefly from east-northeast—were very frequently unsettled, seeming to falter, circle, and then move on. The wind vane at that time was oscillating between north and east-northeast. However, at 4 p. m. the wind having fallen, to all ordinary appearance, mischief was not expected. About 1 a. m. on the 2d instant the wind rose in fierce gusts from the north. This was the first indication of coming trouble. My barometer registered 29.602" at

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[1] "Handbook of Cyclonic Storms," p. 268 ff.

1 a. m.' The mercury continued to fall; at 2 a. m. it registered 29.404"; the wind vane circling at very great speed, and the wind so strong apparently from northeast, that I could not force my way up the ladder to the anemometer. At this time the shingles from the convict barracks and hospitals were being ripped up by the wind. The I. M. S. *Enterprise,* then in harbor, was either being driven or was forcing her way out at the southern entrance of the Ross harbor, and was whistling, apparently in distress (for, as it so happened, it was their death signal). She was driven on the rocks when about halfway out and was a total wreck, losing all but six hands, before daybreak. Between 2 and 3 a. m. there was a sudden lull, then the wind veered round to southward, and by 3 a. m. the cyclone was at its worst. The barometer reading was 28.502"; and, after a very hard struggle to reach the anemometer, a reading was registered as 499.9. Two steam barges, several large lighters, and many boats in the harbors had lost their anchorage, and were at the mercy of the wind and waves. They have all been more or less smashed or otherwise destroyed. Trees of great size were ripped up by the roots. Cocoanut trees were broken off at the crowns like mushrooms; areca-nut trees snapped like matchwood, and the roofs and sides of nearly every building destroyed. At 4 a. m., the barometer rose to 28.680". Another attempt was then made to reach the anemometer. This was accomplished with very great difficulty, and the reading taken at 105 + 1.4 miles, so that in the hour the wind traveled 505 − 499.9 + 106.4 = 111.5 miles. The wind vane had been wrenched off. About fifteen minutes after leaving the anemometer the cups were wrenched off too; the platform and hand rail leading to the instruments were broken off."

The more important inferences from the account are:

First. The storm consisted of an inner area of destructive hurricane winds and of an outer area of comparatively moderate winds.

Second. The inner storm area of hurricane winds was not more than 45 miles in width on the east side of the island, and 38 miles on the west side.

Third. The diameter of the storm area in which the winds were strong enough to break the branches of trees was 54 miles.

Fourth. The strongest winds, according to Mr. Carroll, lasted from 1 a. m. to 5 a. m., giving a duration of four hours for the passage of the inner storm area across Port Blair, corresponding to a diameter of 75 miles (assuming the velocity of the storm at this stage to have been 18¾ miles).

Fifth. The inner storm area was, hence, almost certainly elliptical shaped, the longest diameter (lying east and west) probably not exceeding 75 or 80 miles, and its shortest diameter (lying north and south) not exceding 50 miles. A comparison of these data with those of the dimensions of the inner storm area or typhoon when crossing the Malayan Peninsula shows that the storm was practically unchanged in shape or dimensions, and that the direction of the longer diameter of the storm area in both cases approximately coincided with the direction of advance of the storm. * * *

November 3.—The barometric changes of the previous twenty-four hours were small in amount at all the Indian land stations, and under ordinary circumstances would have been considered of little or no significance.

Skies were thickly clouded in Burma and were clouding over in Bengal.

The rapid extension of clouds over the bay area and in Bengal and the peninsula is one of the most characteristic features of storm in the Bay of Bengal. * * *

November 4.—Pressure had decreased over the whole of India. The fall was greatest in the Madras, Orissa, and West Bengal coast districts where it ranged from a tenth to a sixth of an inch. Skies were overcast in the North Madras coast districts, and were more clouded than hitherto in Bengal. Rain had, however, not yet commenced to fall in the coast districts of North Madras or in Orissa or Bengal.

The storm center passed a little to the east of Gopalpur and Puri during the morning and over False Point in the afternoon. It advanced about 25 miles to the east of Shortts Island at the mouth of the Dhamrah River late in the evening.

The storm center passed over False Point in the afternoon between 4.05 p. m. and 4.45 p. m. Two series of observations are available, one taken by the observer at the light-house and the other by the port officer.

The central calm area passed over the light-house between 4.05 and 4.45 p. m., and hence lasted forty minutes. As the storm was progressing at the rate of nearly 9 miles an hour, the greatest diameter in a north-and-south section was between 5 and 6 miles. The port office was just on the outer western edge of the calm center. The port office bears north-northeast (vide Taylor's Directory) from the light-house.

The False Point observations throw light upon several interesting features of cyclones. The following are the most noteworthy points:

First. The passage of the calm central area over the light-house lasted more than half an hour, and hence afforded ample time to test the pressure and air-motion conditions in and near the calm area. The calm lasted from 4.05 p. m. to 4.45 p. m. As described by the observer, the wind, which was blowing a moderate gale at 4 p. m., fell to a dead calm at 4.05 p. m. The transition was hence abrupt, but less so than is usually indicated by the remarks in the logs of ships that have passed through the central calm area of cyclones. The dead calm was followed by light variable winds until 4.45 p. m., after which the wind increased very rapidly and was blowing with hurricane force at 5 p. m. These observations hence indicate that the transition from the central calm to the hurricane winds just outside the central calm area is less rapid than is usually supposed, and that the change is rapid and gradual rather than abrupt and spasmodic.

The False Point port officer added the following remarks to the observations which he forwarded:

"I would also beg to say that this has been one of the most severe cyclones that I have experienced during my long residence of twenty-six and one-half years at False Point. The whole of the station, except the refuge building, is in ruins, but I am happy to say that no lives have been lost.

"The whole of the beacons marking the harbor have been blown away, and Reddie Head Sand Spit has entirely disappeared. Yesterday afternoon I pulled across in my boat what used to be dry sand and found nothing less than 6 feet of water."

Intensity of the storm as gauged by the maximum depression of the barometer.—The following give the lowest barometric readings actually observed in or near the calm central area on different dates:

Place.	Day.	Hour.	Position with regard to calm center.	Barometer corrected and reduced to sea level and constant gravity.	Variation from normal of day.
				"	"
Port Blair	Nov. 2	2.00 a. m	9 miles from central area	28. 254	—1. 55
Do	do	3.00 a. m	5 miles from central area	28. 359	—1. 43
Puri	Nov. 5	6.00 a. m	25 miles from central area	29. 068	—0. 77
False Point light-house	do	3.45 p. m	2 miles in front of calm center	28. 012	—1. 83
False Point port office	do	5.00 p. m	Just outside the calm center	28. 190	—1. 66
Shortts Island	do	8.00 p. m	25 miles north from calm center	29. 028	—0. 86
Intermediate station	Nov. 6	2.00 a. m	In calm center	28. 670	—1. 22
Lena	do	1.15 a. m	do	28. 000?	—1. 89
Lincolnshire	do	2.00 a. m	5 to 10 miles from calm center	28. 860	—1. 03
Japan	do	2.20 a. m	20 to 30 miles from calm center	29. 150	—0. 78

A consideration of these facts and of the observed pressures at distances of 10 to 30 miles from the calm central area appears to establish the following inferences:

(1) From the morning of the 2d (and probably from the afternoon of October 31) up to midnight of the 5th or 2 a. m. of the 6th the minimum pressure in or just outside of the calm area was less than 28.1 inches, and was very probably slightly below 27.75 inches on the 1st and 2d.

(2) The maximum depression in and near the calm central area hence undoubtedly ranged between 1.6 inches and 1.83 inches during this period, and was very probably slightly greater than 2.1 inches on the 1st and 2d.

(3) It would hence appear that the maximum barometer depression, and therefore the pressure conditions of the calm central area were remarkably uniform during the whole of this period from the 31st to the afternoon of the 5th, including an interval of nearly 6 days; thus indicating a remarkable persistence and steadiness of the conditions of the central calm area and inner storm area, or core of the storm.

Intensity of the storm as measured by the magnitude of the steepest gradients in the storm area.—The unit of gradient adopted by European meteorologists is 0.01 inch per 15 geographical miles. The mean pressure difference during the southwest monsoon period is barely 0.3 inch over the Bay of Bengal between latitude 7° N. and latitude 22° N. This mean pressure difference over the bay corresponds to a mean gradient of nearly 0.5. The gradients of course vary in different parts of the Indian land and sea during the southwest monsoon, but they probably rarely exceed 1 or 2, except in the neighborhood of, or within any area affected by, a cyclonic storm of the rains. It may also be noted that gradients seldom exceed 5 to 10 in European cyclonic storms.

The following gives the steepest observed gradients in the Port Blair cyclone as determined by accurate observations taken at the two land observatories in its path:

Station.	Interval.	Difference of pressure.	Gradients.[1]
	Hour.	*Inch.*	
Port Blair	1 to 2	[2]0.20	67½
False Point light-house	14 to 14.30	[2].372	112
	14.30 to 15	[2].302	91
	17 to 17.30	[3].306	92
	17.30 to 18	[3].310	93
False Point port office	15 to 15.30	[2].200	60
	15.30 to 15.45	[2].100	60
	15.45 to 16	[2].180	108
	17 to 17.30	[3].110	33
	17.30 to 18	[3].270	81

[1] The gradients are expressed according to the international system—that is, in hundredths of an inch per 15 nautical miles.

[2] Fall.

[3] Rise.

If it be assumed that the lowest pressure at Port Blair was 27.75 inches and that it occurred between 2.20 to 2.35 a. m., this would give a fall of pressure of half an inch in a distance of 7 to 12 miles. The former would correspond to a gradient of nearly 110, agreeing closely with the observed gradients at False Point. It should also be noted that these are mean gradients based on observations taken at half or quarter hourly intervals; and hence not the maximum gradients at any instant during any one of these intervals. It is almost certain that the steepest gradients exceeded 120.

The following conclusions respecting the steepest gradients in this cyclone are based on the previous data and the connected considerations:

(1) The steepest horizontal gradients in the storm were in the front or advancing quadrant and almost certainly exceeded 100, and probably slightly exceeded 110 during by far the greater part of the existence of the storm. These are the mean gradients based on observations taken at quarter or half hour intervals, and it is possible that the steepest gradients may have been at least 25 per cent greater, and may have exceeded 150.

(2) The steepest horizontal gradients observed in the western or retreating quadrant ranged between 80 and 100, and were about 20 per cent smaller than the steepest gradients in the advancing quadrant.

(3) The maximum gradients in the inner storm area were almost certainly remarkably steady from the evening of the 1st and probably from the evening of the 31st until midnight of the 6th, and probably did not, under similar conditions of measurement, vary more than 10 per cent during this interval.

(4) Hence the maximum gradients near the calm central area in this storm, as well as the maximum barometric depression were remarkably steady and uniform during a period of at least six days.

The preceding data hence establish that the mean pressure in or just in front of the central calm area from midnight of the 5th averaged 28 inches, the maximum depression averaged 1.9 inches, the maximum gradients in the advancing quadrant averaged 110, and the retreating quadrant averaged 90. The variation in these elements during the whole period was almost certainly less than 20 per cent, and probably not more than 10 to 15 per cent.

Magnitude of the storm.—The calm central area when passing centrically over Port Blair and the barque *Safir* was nearly 5 miles in width in an easterly and westerly direction or in the then direction of advance of the storm. It passed centrically over False Point light-house on the afternoon of the 5th, and its diameter in the direction of advance of the storm was slightly greater than 5 miles. Considering the character and phenomena of the storm during the whole of its existence and the remarkable permanence of the chief features of the storm during the greater part of its existence, it is almost certain that there was a well-defined calm central area from the afternoon of the 31st up to 3 or 4 a. m. of the 6th, and that it formed one of the more conspicuous and important features of the storm. Its diameter in the direction of advance of the storm was practically the same in length on the 5th as on the 2d, the only days for which there are data that enable it to be approximately measured. It is hence very probable that during the whole of the period from midnight of the 31st to that of the 5th the calm central area was practically unchanged in magnitude.

There are no data from which an estimate of the shape of the calm area of the storm at any stage can be directly inferred. It is, however, most probable that it was, like the inner storm area, elliptical shaped and that its greatest diameter was in the direction of the advance of the center and approximately 5 miles in length.

The inner storm area or area of fierce and destructive winds (force 10 to 12) has been ascertained at several stages throughout the storm. It was probably about 60 miles in its longest diameter and 30 miles in the shortest diameter when crossing the Malayan Peninsula. When advancing over the South Andaman Island it was between 70 and 80 miles in length by 50 to 60 miles in breadth. The inner storm area appears to have taken between eight and nine hours in passing over False Point light-house. The rate of advance of the storm at that time was nearly 10 miles an hour. The diameter of the inner storm area (in the direction of advance) was hence at that time probably between 80 and 90 miles.

The whole of the data strongly support the inference that the inner storm area was practically unchanged in shape and extent from the evening of the 31st to that of the 5th. It was almost certainly elliptical shaped throughout, its largest diameter averaging 80 miles and shortest diameter (probably) 60 miles. The direction of its longest diameter coincided approximately with the direction of advance of the storm center throughout its existence.

It is much more difficult to estimate the extent of the outer storm area. It is, however, certain in the present case that when the storm entered the Andaman Sea it did not affect the weather and winds to any considerable extent at distances of 100 miles to the north and south. As it advanced over the bay the area of strong winds and squally to stormy weather increased largely in extent. The extension occurred chiefly in the eastern and southern quadrants, where the indraft to the cyclonic storm intensified the southwest monsoon humid winds. For example, on the 5th, winds of force 8 (moderate gale) were experienced at distances of at least 300 to 350 miles from the center in these quadrants.

Hence the important inference that the calm central area and the inner storm area were almost unchanged in extent, and in several other characteristic features from the 1st to the 5th, but that at a very considerable extension occurred during this period in the outer storm area. The extension was greatest and most marked in the eastern and southern quadrants, the quadrants into which the humid winds that maintained the storm were chiefly drawn.

Calm center.—The features of the calm center of the cyclone, as far as they are indicated by the observations taken at False Point and Port Blair, have been fully described in the body of the report. The following gives a summary:

(1) Pressure was lowest at some little distance in front of the calm area.

(2) Pressure was not quite uniform in the calm area but increased slightly in proceeding along the diameter, coinciding with the direction of advance and in the opposite direction.

(3) The air was practically, if not absolutely, calm within the calm area proper.

(4) The transition from the hurricane winds in front to the central calm was not sudden, but gradual; and similarly in the rear the transition from the calm to hurricane winds was not instantaneous, but gradual. This is fully established by the observations taken at the False Point light-house.

(5) The observer at the False Point light-house thus describes the appearance of the sky when the calm center was passing over it: "The sky was covered with broken clouds, and there was a heavy bank to eastward."

(6) The mercury column did not pulsate in the calm area as it did outside of it in the area of hurricane winds and fierce gusts. The light-house keeper at False Point states:

"I noticed that during the approach of the storm the pointer of the aneroid oscillated a good deal, jumping up and down fully one-tenth of an inch, and the same thing occurred when the storm was receding; but during the time the center was passing it remained quite steady. At one time during the approach of the storm the pointer went as low as 28.08" with the oscillation. I have noticed a slight oscillation of two or three hundredths of an inch in other cyclones, but never to such an extent as in this one."

Rainfall.—As the storm passed chiefly over a sea area the data for determining the character and distribution of rainfall accompanying the storm are limited. The rainfall in the storm area while it was crossing the Bay of Bengal was of the usual torrential character. Captain Beahan, of the F. L. V. *Canopus*, at the intermediate station, writes that the rain was heavier than he had experienced in any previous storm at the head of the bay. The commander of the F. L. V. *Foam* states that the storm began at his station with a heavy squall and torrents of rain. The steamship *Saint Regulus* had very heavy rain, the steamship *Japan* continual heavy rain, and the steamship *Lincolnshire* terrific rain squalls.

It is not possible to deduce with certainty the character of the rainfall in different quadrants of the cyclone area. The evidence is, however, strongly in favor of the supposition that the rainfall was heaviest in the advancing quadrant. Puri is a striking example. The center was 10 miles to the east of Puri at 8 a. m. of the 5th. During the previous twenty-four hours 13.61 inches of rain had fallen, and during the next twenty-four hours only 1.80 inches were received. Equally strong evidence is furnished by the rainfall at False Point, where 11.06 inches fell during the storm. The rainfall at False Point was heaviest and most intense between 2 p. m. and 4 p. m., and hence in the advancing quadrant.

The rainfall data of the storm hence suport the following inferences:

(1) The rainfall accompanying the storm was excessive and torrential in character while it was in full vigor.

(2) The rainfall diminished rapidly on the 6th while the storm was filling up, and practically ceased before the residual depression had disappeared.

(3) The rainfall was heaviest in the advancing quadrant, not only while the storm was fully developed, but also while it was filling up.

Strength of the winds in the inner storm area.—The winds were exceptionally violent in this cyclone. The anemometers and wind vanes were blown away at four observatories, viz, Port Blair, False Point, Puri, and Shortts Island. The center passed over the first two. Puri was about 10 miles from the center when it was nearest to it, and Shortts Island 25 miles.

The following gives the greatest wind velocity as recorded by the anemometers at the stations in and near the calm central area during its progress:

Station.	Air movement, in miles per hour.
Port Blair	111.5 miles, 4 a. m. of the 2d.
Gopalpur	42 miles, at 11 p. m. of the 4th.
Puri	96 miles, at 9 p. m. of the 4th.
Shortts Island	64 miles, at 4 p. m. of the 5th.
Sangor	77 miles, at 5 a. m. of the 6th.

The velocity was determined in the cases of Puri, Shortts Island, and Saugor Island by means of observations of the anemometer taken at intervals of three minutes, and hence represents very approximately the velocity at the times of observation.

It is hence very probable, if not almost certain, that in the strongest blasts the air velocity was certainly not less than 120 miles per hour and may have been as much as 150 miles, corresponding according to the usual formula to a horizontal pressure of about 90 pounds per square foot on an obstacle. Assuming the known maximum gradients in this storm and using Ferrel's formula giving the relation between the baric gradient and air velocity in cyclones, we get a velocity of about 130 miles per hour.

Secondary whirls.—A noteworthy feature of this storm was the existence of small subsidiary whirls as part of the large general disturbance. There is some evidence of the existence for a short time of certainly two, and perhaps of three, subsidiary whirls in this storm. They were observed in the following cases:

(1) By the steamship *Arratoon Apcar* on the 3d, 300 miles to the southeast of the storm center.

(2) At Gopalpur on the 5th.

(3) In the Hooghly near Saugor Island on the 5th.

The first is the most remarkable.

Recurvature of storm.—The Port Blair cyclone during the first three or four days of its existence traveled in the ordinary direction of storms passing across the center of the bay in the month of November, viz, west-northwest. When it had advanced as far as the center of the bay, it began to recurve to north. As it approached the west coast of the bay it recurved more or less steadily on the 3d, 4th, and 5th, and the total recurvature of the storm was larger than in any storm in the bay on record. Its track was N. 69° W. when it entered the Andaman Sea, and N. 55° E. when it passed into Bengal. The total recurvature during its passage across the Andaman Sea and Bay of Bengal was hence 124°. This occurred, as already stated, on the 3d, 4th, and 5th.

As invariably happens when a storm recurves in the bay, the rate of advance decreased very considerably and varied to some extent with the amount of recurvature. The velocity of the storm center, which averaged approximately 20 miles on the 31st, 1st, and 2d, decreased to 9 miles per hour on the 3d and 4th, and increased slightly on the 5th and 6th to an average of 12 miles for the twenty-four hours preceding 8 a. m. of the 7th.

That recurvature should cause a decrease in the rate of advance of the storm is in accordance with ordinary mechanical principles. The general tendency of cyclonic storms in the Bay of Bengal is to advance in approximately straight tracks over the sea area. If they recurve it is due to some obstruction or obstructive action, the conditions being such as to enable the storm to change its path without its rotary motion being broken up. * * *

The following table gives data showing the amount of recurvature from the 2d to the 6th and the velocity:

Date.		Hour.	Direction.	Change in previous 24 hours.	Velocity.	Change in previous 24 hours.
				°	*Miles.*	*Miles.*
Nov.	2	8.00 a. m.	N. 70° W.		450	
Nov.	3	8.00 a. m.	N. 62° W.	8	280	−170
Nov.	4	8.00 a. m.	N. 42° W.	20	220	− 60
Nov.	5	8.00 a. m.	N. 7° E.	49	250	+ 30
Nov.	6	8.00 a. m.	N. 43° E.	36	230	− 20

Track and rate of advance.—The following table gives the position and rate of advance of the storm center at intervals during the existence of the storm from November 1 to 6:

Date.		Hour.	Place.	Position.				Distance passed over during interval.	Average rate of motion per hour.
				Latitude (north).		Longitude (east).			
				°	′	°	′	*Miles.*	*Miles.*
Nov.	1	1.30 a. m.	Chaiya	9	10	99	16		
		3.00 a. m.	Kapu					40?	
		8.00 a. m.	do	9	50	97	30	150	23.1?
Nov.	2	2.30 a. m.	Port Blair	11	40	92	40	330	17.8
		8.00 a. m.	Mid bay	12	10	91	10	115	20.9
Nov.	3	8.00 a. m.	do	14	10	87	20	275	11.5
Nov.	4	8.00 a. m.	About 100 miles southeast of Vizagapatam.	16	25	85	5	220	9.2
Nov.	5	4.00 a. m.	50 miles east of Gopalpur	19	25	85	40	208	10.4
		8.00 a. m.	15 miles east of Puri	19	45	86	5	35	8.8
		4.20 p. m.	False Point	20	20	86	47	65	7.8
		9.00 p. m.	20 miles east of Shortts Island	20	45	87	15	32	6.9
Nov.	6	2.00 a. m.	Sandheads	21	15	87	51	48	9.6
		8.00 a. m.	East of Saugor Island	21	45	88	45	70	11.6

II. THE CHITTAGONG CYCLONE, OCTOBER 15 TO 25, 1897.

Concerning this typhoon we spoke to the following effect in the meteorological review for October, 1897:

At 4 p. m. of the 17th the observatory announced the existence of a new depression to the southeast of Manila; and at 10 a. m. of the 18th its progressive movement in the interior of the Archipelago was noticed in the following terms: "Pressure tends to rise in the south and to fall slightly on the western coasts owing to the movement of translation of the depression mentioned yesterday. The depression is crossing the southern part of the Archipelago in the direction of the China Sea. * * *" The data which we have recently received from the Islands of Mindanao, Negros, and Paragua confirm the notices given out by the Observatory. The typhoon, in effect, entered Mindanao on the night of the 16th and passed close to Linguig, where the winds were so strong that out of the 80 houses that formed the village only nine were left standing, and of these nine four, including the court-house and the convent, were greatly shaken. The vortex probably left Mindanao by the north of the Iligan Bay between 10 and 11 o'clock of the morning of the 17th, for between 3 and 4 p. m. it penetrated into Negros by the south of the island, making itself felt in Dumaguete with hurricane winds from the east, while strong winds blew from the southwest in Dapitan. About noon the vortex entered Paragua, passing close to Barbacân where the violence of the winds razed to the ground the greater part of the houses in the town and uprooted a great number of trees.

There were but few observations taken in the points where the vortex passed, owing to the lack of good instruments, still, more or less exact data were received from four towns situated fairly close to the vortex which serve admirably to fix the trajectory.

Linguig (latitude, N. 8° 2′; longitude, 126° 22′ east of Greenwich) and **Catel** (latitude, N. 7° 51′; longitude, 126° 21′ east of Greenwich).—Fr. Mateo Gisbert, S. J., missionary in Baganga, wrote that "this typhoon of the 16th of October was very destructive in the villages of Catel and Linguig." Although he does not give us more details concerning Catel, still we have from another letter of his that "in Dalumbana, an island situated near the coast and to the east of Catel, there was a typhoon on the 16th which destroyed houses, convents, and abacá stores and tore off the roofs of the church, court-house, schools, etc."

Fr. Matias Roure, S. J., describes the violence with which the storm broke over Linguig in these terms:

> On the 16th the morning broke rainy with slight winds from the northwest. By 7 p. m. the rain had ceased, but the wind had increased in violence. At 9.30 the gusts were so intense that there was no doubt that there was a typhoon. At 10.30 the wind changed, veering to the east where it was the most violent, throwing down almost all the houses and uprooting trees. The rain continued till the wind veered again to the south at about 1 a. m. In proportion as the wind veered to the south its force decreased, so that the morning of the 17th broke with fine weather and the winds blowing from the south.

Veruela (latitude, N. 8° 2′; longitude, 125° 47′ east of Greenwich).—We are indebted to Fr. Fernando Diego, S. J., for some interesting data concerning this typhoon, which after passing as we have seen by the south of Linguig at 10 p. m. of the 16th, crossed by the north of the east of Veruela about 2 a. m. of the 17th.

> The typhoon of the 16th and 17th was very destructive judging from the effects of it which I have seen; not only were trees uprooted but the canes were twisted as if they had been pieces of string. At daybreak of the 17th it appeared as if an enormous, heavy wheel had passed over the country. The morning of the 16th was calm with light rain, and in the evening it was also very calm, but the rain was more abundant. At 9 o'clock the strong winds began, and at 11 p. m. the hurricane commenced. The winds reached their maximum strength about 2 a. m. The rain which followed was torrential. As to the direction of the wind I would say that it started northeast followed on to north, then northwest, and finally finished at south; the greatest strength was in the direction northwest. On the morning of the 17th I saw a long band of black ruins which indicated the situation of the vortex (the path of the cyclone).

Tagoloan (latitude, N. 8° 33′; longitude, 124° 40′ east of Greenwich).—Fr. Juan Bt. Heras, S. J., wrote the following from Tasaan:

> The typhoon of the 16th and 17th of October broke with heavy rains in the valley of Tagoloan which, according to the older men, produced the greatest flood which has happened for the last twenty years. I was in St. Ana (latitude, N. 8° 33′; longitude, 124° 52′ east of Greenwich) and saw a part of Tagoloan in flood so that the road from St. Ana to Tagoloan was interrupted in several points by the waters.

Dumaguete (latitude, N. 9° 19′; longitude, 123° 17′ east of Greenwich).—The vortex in its track moved approximately west-northwest, as we learn from observations made in Dumaguete (southeast Negros), then passed by the south and very close to the said town. From other points in the south of the track in the north of Mindanao we can only say that in Marahui (Laguna de Lanao), as in Iligan and Dapitan, it is certain that strong winds from west and southwest were felt on the 17th with rain and squalls.

Barbacan (latitude, N. 10° 22′; longitude, 119° 22′ east of Greenwich).—From a letter received from the governor of Paragua, D. Angel Lopez, we can follow this typhoon till it crossed that island in the direction of the China Sea. He says:

> On the 18th of October a typhoon passed over Barbacán; it lasted from 9 a. m. till 2 p. m. and overturned the greater part of the houses in the town and uprooted a great number of trees.

Conclusion.—From these observations we deduce that the typhoon entered the Archipelago by the south of Linguig at 10 p. m. of the 16th and reached Barbacan by noon of the 18th. It moved, therefore, in the direction west-northwest, and in its passage of about 420 miles, the distance which separates the two places, it occupied thirty-eight hours. Hence we conclude that it traveled at the rate of 11 miles per hour in crossing the Archipelago.

A little after noon of the 18th the vortex was to the west of the north of Paragua. From the data received from the vessels which were in the China Sea at this time we can follow the movements of the center as far as the coast of Cochin China.

The German steamer *Sachsen* left Singapore on the 14th and reached Hongkong on the 20th. In the southern part of the China Sea she had light southerly winds and in the northern part (on the 18th, 19th, and 20th) strong to stormy northeast monsoon with high sea, swell, and squally weather. These strong winds from the northeast could not be attributed to the other terrible typhoon (the Samar and Leyte typhoon), which already on the 16th had penetrated the coast of Cochin China close to the 16th parallel north.

The British steamship *Faichiow* left Bangkok on October 11 and Koh-si-chang on the 15th, and had light to moderate winds and fine weather as far as Cape Padaran, which was passed on the 18th, when a strong northerly wind set in with threatening weather and a falling barometer. On the 19th she ran for Ongro Bay and anchored there at 8 p. m., the weather meanwhile becoming more threatening and the barometer still falling. At 9 p. m. the barometer fell to 29.28 inches, accompanied with terrific squalls and blinding rain. Wind very unsteady from north-northwest to south-southeast and south. At 11 p. m. the typhoon had passed and the wind had steadied at southeast. At 8 a. m. on the 20th she proceeded to Hongkong, had moderate to light east-southeast to north winds to 100 miles south of Hongkong; thence to port, strong northerly wind and clear weather.

The typhoon then entered Cochin China between the Capes Padaran and Varel, somewhat closer to Cape Padaran, between the hours of 9 and 11 p. m. of the 19th. It had traversed the China Sea with almost the same velocity with which it had passed the Archipelago. We lack data to prove with certainty the course of this typhoon in the interior of Cochin China. Still, as all the observations made in the Straits Settlements indicate the passage of a depression by the north of the Gulf of Siam on the 20th and the 21st, it is very probable that the cyclone which appeared on the morning of the 21st in the Bay of Bengal was that which we have been following from the Archipelago. Although we are in want of positive data, it is probable that the energy of the typhoon was weakened in crossing Cochin China and the high part of the Malay Peninsula, as several observations quoted by Mr. Eliot indicate. Mr. Eliot describes the origin of the storm in the following words:[1]

> **Origin of the storm.**—Weather was fine with light winds over the south and east of the bay on the 20th. According to newspaper accounts, weather had been stormy in the China Sea during the previous week or ten days. If this information be correct, it is probable that the rapid fall of pressure and appearance of a low-pressure area suddenly and with little or no warning in the north Andaman Sea during the next twenty-four hours was due to the movement of a storm depression from the Gulf of Siam across the north of the Malay Peninsula. If this be the case, the storm was at this stage either of small extent or of very feeble intensity and the winds and weather at Tavoy, Mergin, and Port Blair were very slightly affected by it, and the strongest winds experienced by the vessels in the Andaman Sea were of force 4 to 5.
>
> The observations indicate that there was at 8 a. m. of the 21st a depression in the north Andaman Sea, the center of which was in about latitude 14½° N. and longitude 96° E. Skies were clear or lightly clouded at 8 a. m. in Upper and Central Burma and overcast in Lower Burma, but no rain had fallen except in Tenasserim. Weather had changed rapidly in the Andaman Sea and was squally with heavy rain at 8 a. m.
>
> There are no data available giving direct information of the extent and intensity of the storm, but, judging from the irregularity of the wind directions at the coast stations and the comparatively feeble winds actually

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[1] "Handbook of Cyclonic Storms," etc., p. 291 ff.

recorded by vessels in the bay and at the coast stations, it is very probable that at this stage the storm was of small extent as well as of moderate intensity. This is in agreement with the supposition that it had crossed the Tenasserim mountain range between latitude 13° N. to latitude 15° N., where it reaches an average elevation of about 4,000 feet.

The Diamond Island observations indicate that the storm center passed to the southwest of that station between 8 p. m. of the 21st and 2 a. m. of the 22d and was probably nearest to that station very shortly before 2 a. m., when it was probably not more than 40 or 50 miles to the southwest. The observations give very interesting information of the variations in the intensity of the winds during the storm at that station, more especially in the northwestern quadrant. The highest recorded winds had a velocity of 60 miles per hour, and the lowest recorded pressure was 29.542" at 2 a. m. The observations suggest that the storm was developing rapidly and increasing in intensity at that time.

The data indicate that the center at 8 a. m. of the 23d was probably a little to the west of the position of the steamship *Maharani* at 8 a. m., or in about latitude 18½° N. and longitude 91° E. She had violent winds of force 10 and blinding rain throughout the day and was nearest to the storm center in the evening at about 6 or 7 p. m., at which hour a heavy, confused sea prevailed. Weather was stormy with terrific squalls and violent winds at 8 p. m. The weather began to moderate about midnight.

The 8 a. m. data, extracted from the logs of vessels in the storm area on this day, indicate that the storm center at 8 a. m. of the 24th was in about latitude 20½° N. and longitude 90¾° E. or longitude 91° E. All the vessels contributing information were at considerable distances to the south and west of the center. Their observations indicate clearly the extension of the stormy weather in the north of the bay. The steamship *Maharani*, which was about 240 miles to the south-southeast of the storm center, had winds of force 10 and terrific squalls. The *Karagola*, 100 miles north, had violent rain squalls. The steamship *Pandua*, 150 miles farther west, had south-southwest winds, force 8, a high sea, and violent squalls.

The storm hence was now one of great intensity, but the observations at the land stations continued to show that the inner storm area was of small extent. The storm center passed over or near to Chittagong during the evening, as is shown by the following observations taken at that station:

Hour.	Barometer reduced to sea level and constant gravity at latitude 45°.	Direction of wind	Weather.
	"		
4.53 p. m.	29.231	ENE.	Cyclonic storm blowing, squalls heavy, occasionally with heavy rain.
5.47 p. m.	.097	ENE.	Cyclone blowing furiously; exceedingly heavy squalls, occasionally with heavy rain.
6.13 p. m.	.018	ENE.	Severe cyclone blowing, large branches of trees falling, and telegraph lines interrupted.
6.35 p. m.	.018	ENE.	Severe cyclone and squalls with heavy rain and lightning.
6.56 p. m.	28.817	N.	Severe cyclone and squalls with heavy rain and lightning; wind more north.
7.20 p. m.	.747	N.	Severe cyclone and squalls with heavy rain and lightning; wind tending to E.; heavy rain, lightning, and hail.
7.44 p. m.	.680	NE.	Severe cyclone and squalls with heavy rain and lightning; terrific squalls, occasionally with heavy rain and lightning.
8.40 p. m.	.799	NNW.	Severe cyclone and squalls with heavy rain and lightning; wind tending NW.
9.28 p. m.	29.120	NW.	Cyclone considerably moderated; wind light and occasional squalls and very heavy rain.

The storm center as shown by these observations passed over or near to the Chittagong observatory between 7.45 p. m. and 8 p. m. Hurricane winds prevailed in the inner storm area and caused great destruction of property and crops in the belt over which it passed. Pressure at the storm center was at least 1.2 inches below the normal. As the storm approached the coast about the time of high water, the storm wave which accompanied it was of destructive violence and overflowed the low grounds in the Islands of Kutubdia, Matarbari, and Moiskhal and the low coast districts between Chittagong and Ramree.

Heavy rain fell during the twenty-four hours preceding 8 a. m. of the 25th in a part of the Chittagong district and the South Lushai Hills. The fall in several cases varied between 7 and 10 inches.

The superintendent of the South Lushai Hills reports that it began to blow hard at 9 p. m. and by 10 p. m. there was a hurricane accompanied by pelting rain. The storm abated at 12.30 a. m., having in the meantime made great havoc in the buildings and trees.

Track of the storm.—The following table gives data showing the position and average rate of movement of the storm center from the 21st to the 24th:

Date.		Position of center at 8 a. m.				Distance traveled during interval.	Average hourly rate of motion during interval.
		Latitude (north).		Longitude (east).			
		°	'	°	'	*Miles.*	*Miles.*
Oct.	21	14	30	96	00		
Oct.	22	16	30	92	30	275	11½
Oct.	23	18	30	91	00	170	7
Oct.	24	20	30	90	45	142	6

The storm wave.—The main force of the cyclone on the 24th was confined to a strip extending from about 14 miles above Chittagong town on the north to a point some 4 miles below Cox's Bazar on the south, about 70 miles wide in all. North and south of this strip little damage was done, but within it the force of the cyclone was very great. The portions swamped by the storm wave consisted of the Islands of Kutubdia and Matarbari and a strip of low land on the mainland opposite. The area of the tracts affected was about 225 square miles. Of this some 32 miles should be deducted for mangrove jungle, leaving. 193 miles of cultivated lands affected.

The storm was in several respects similar to the storm which passed over and wrecked Port Blair in November, 1891. Like that storm, it crossed the Malay Peninsula from the Gulf of Siam and was of small extent but of great intensity, the winds in the inner storm area being of hurricane force. It passed by an east-northeast path across the north of the Andaman Sea through the Preparis North Channel into the Bay of Bengal and thence recurved through northwest to north and finally to north-northeast, passing across the Chittagong coast as a small storm of great violence. The storm winds and rain caused great destruction of crops and property, and the storm wave flooded the low coast districts, causing the death of at least 7,000 people.

The greatest part of the storm and the advance of the storm wave took place in the dark, and this circumstance materially increased the loss of life. According to a statement derived from imperfect police reports, the number of deaths reported was 7,401.

The collector, after visiting the littoral tracts, says that in many cases the village sites had been obliterated and everything swept away. In these villages the mortality among women and children was very great. In the case of four villages which he visited he says that the few survivors had lost everything. They were clothed with rags found in the jungles and were living in rough huts made out of jungle and the fragments of their ruined houses. They were eating the half-ripened rice from their fields and drinking brackish water.

The estimate of the number of deaths given above is almost certainly considerably below the actual, which was probably 10,000 or 12,000 at the very least. A disproportionate number of these were no doubt women and children who had not the strength and activity to take refuge in trees.

The destruction of cattle was also on a very large scale, but the measure of the loss is at present impossible to estimate. In one village in which there were formerly 3,000 head, only 90 remained after the storm.

CHAPTER IX. THE ANOMALIES IN CYCLONES.

REAL AND APPARENT ANOMALIES.

Introduction.—In this last chapter we intend to treat of anomalous cyclones, or the anomalies in cyclones. The abundant material would require a lengthy discussion if our aim were not purely practical, because the exceptions to the laws are manifold, and precisely because they are exceptions they can not be reduced to a formula nor grouped under certain headings or made the subjects of practical rules. On the other hand, it suffices the observer to know that in a given case he is under the influence of anomalous conditions; he will still guide himself by the known laws, but with special care and circumspection. Luckily these anomalies are, as constant experience teaches, usually little to be feared, their ordinary effect being to oblige the observer to proceed with a little extra precaution.

We must distinguish between two kinds of anomalies—real anomalies and such as are only apparent. To the former class belong all those phenomena which really constitute an infraction of the known laws of typhoons or a departure from the ordinary course of events observed in connection with a cyclonic storm, it being immaterial whether this connection is essential or not. Hence anomalous typhoons, strictly speaking, are: Stationary typhoons, typhoons without rain, considerable depressions without wind or with but little wind, shallow depressions with very violent cyclonic winds, typhoons traveling in a southwest direction, etc. Apparent anomalies, on the contrary, are those caused by forces which have nothing to do with the cyclone itself. To this class belong simultaneous typhoons (twin typhoons), secondary cyclones, cyclones broken up by polar or equatorial currents or by other causes, etc.

We will briefly consider the principal kinds of each class.

REAL ANOMALIES.

Stationary cyclones.—According to an opinion which does not lack probability, a thermic inequilibrium between a central area and an adjacent circular zone suffices to set up and maintain, for a time at least, a cyclonic movement. If this be true, we must admit that the translatory movement commonly observed in cyclones is not essential, and it is easily understood that, the cause of the disturbance being confined to a certain place, the resulting storm must be stationary.[1]

> The conditions of an ordinary stationary cyclone are found in summer on every island in the ocean, for since the annual range of temperature on land is much greater than that of the ocean, the mean annual temperature on land and sea being very nearly the same, the island in summer, especially in high latitudes where the annual temperature changes are great, becomes very much warmer than the surrounding ocean. And this is not merely an incipient condition, such as is required generally to originate a cyclone when the other conditions of proper vertical temperature gradient, and hygrometric state are present, but it is continuous, especially during the day, and keeps up the vertical and cyclonic circulation independently of other conditions.[2]

This view might account for the existence and behavior of low-pressure centers, which occasionally form in north Luzon, on the island itself, during the hottest months of the year, and which for several days do not show the slightest sign of the translatory movement. If so, north Luzon would behave like an island for itself, since south Luzon, being so much nearer to the equator has a correspondingly smaller thermic oscillation.

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[1] Ferrel, "A Popular Treatise on the Winds," p. 318, No. 210.

[2] Ibid, p. 321, No. 212.

However, we prescind from these questions, nor do we wish to decide the question whether translatory movement is essential to every cyclone or not. We merely wish to state the fact that at Manila we have frequently observed cyclones which, according to all indications, remained stationary for a space of two, three, or even more days, as if they had encountered an obstacle to their progress. Sometimes these cyclones were to the northwest, on other occasions to the northeast, of Luzon, causing rain and winds from the third quadrant, phenomena known to the natives as "collas," which usually extend to the Visayas and the southern part of the China Sea. Unfortunately, these cyclones always occur at a considerable distance from Luzon, and so it is impossible to ascertain whether they are absolutely without translatory movement or this is only so small that at a distance the effects are the same which would result if the storm were absolutely stationary. It is clear that in the latter case the anomaly would be only apparent. As the monthly publications of our Observatory show, these cyclones occur chiefly at the end of May and during June and July.

Cyclones without rain.—Rain seems to be an essential for a cyclone, or at least its inseparable companion. Nevertheless, cyclones have been observed—on rare occasions, it is true—which were not accompanied by rain. Such a storm passed over Manila during September 19 to 21, 1891. We have represented its elements on Plate LII (see Chapter VI of this part). An attempt to explain this phenomenon would not contribute anything to the end which we have in view. It may suffice to say that, as the distribution of rain around the cyclonic vortex is so greatly different in various parts, it is by no means impossible that in one or the other instance it may be entirely absent in some parts of the storm area, especially toward the outskirts. In the case under consideration Manila was almost on the outer limit of zone A. We do not know with certainty of a single instance in which a cyclonic vortex swept over a place without being accompanied by rain.

Notable fall of the barometer without corresponding wind.—Although, as has been said, the force of the wind does not depend upon the absolute fall of the barometer, but on the rapidity of the descent, it is not a usual thing to have a considerable fall without wind. Still, a most peculiar case occurred in September, 1894. Though the barometer fell to 745 millimeters (29.39 inches), the wind hardly freshened. Having fully discussed the matter in the pamphlet "Baguios ó Tifones de 1894," we will only remark here that this phenomenon would result if the whole or at least a part of the typhoon were lifted up from the surface in the manner in which tornadoes have been proved to be sometimes carried up into the air.

Strong wind with a slight fall of the barometer.—This noteworthy anomaly has been observed several times, as, for instance, in July, 1895. A typhoon was crossing to the north of Luzon, though at Manila the barometer had not even fallen to 756 millimeters (29.76 inches), the wind blew with the force 7 or 8, a violence which it hardly reaches when a typhoon passes close by to the south. This anomaly can be explained by the existence of a secondary cyclonic nucleus, of which we shall speak anon, or by rapid condensation of aqueous vapors, which may give rise to violent squalls of rain and wind even at great distances from the center if in such places the atmospheric conditions favor abundant precipitation.

Reid tells us that the bark *Ariel* encountered a terrible typhoon November 15 to 18, 1837, though the barometer, according to the report of the ship's captain, Buzt, did not descend below 756.91 millimeters (29.80 inches). All the sails were carried away by the violence of the wind. It seems, however, that we have to deal rather with a barometric error than with an anomaly of the cyclone. The ship's barometer appears to have had a positive error, since, according to the same report, after the passing of the storm it rose within twenty-four hours from 764.53 millimeters (30.10 inches) to 795.01 millimeters (31.30 inches). As the vessel was then between 12° and 14° north latitude, this amount is quite extraordinary, and hence our conclusion.

Cyclones which deviate very much from the mean normal trajectory.—This anomaly is practically very little to be dreaded, because the storm is otherwise normal and the observer on land, and also the mariner sailing on the high sea, has the means to discover these deviations. He needs only attentively watch the changes of his barometer, the surface winds, and the clouds. Moreover, this anomaly is of rare occurrence. In September, 1892, we had a case of this class, and another in September, 1895. It is, however, well worth mentioning that in both instances there existed a simultaneous typhoon.

To this class of anomalies may also be reduced the cyclone observed in October, 1892, which, after recurving in the interior of Luzon, took a perfectly west to east direction.

APPARENT ANOMALIES.

The apparent anomalies are still less to be feared than the real ones, wherefore we shall only very briefly speak of the principal irregularities of this kind.

Simultaneous typhoons.—It occurs pretty frequently that at the same time two or more cyclones become developed. The configuration of the Archipelago seems specially to contribute to this phenomenon. We have already said that in the China Sea typhoons seldom are formed without a cyclone existing in the Pacific, and experience has confirmed this belief. A sailor who notices the indications that a typhoon is developing in the China Sea should remember well that the center in the Pacific, according to its position, may influence the swell, the direction of the drift of clouds, and the direction of the wind. He should, therefore, attribute the irregularity in these observations to this influence. As simultaneous cyclones we may also count the twin or parallel cyclones—hurricanes which originate on the same meridian but in different latitudes and take analogous tracks. They are not rare in the Pacific between the eastern and western Carolina Islands.

There are other cases of simultaneous cyclones during which the state of the atmosphere is extraordinarily complicated. We give one instance. In the monthly bulletin for September, 1902, after having discussed the atmospheric disturbances which occurred at the end of August and the beginning of September, we said:[1]

> From the above we deduce (1) that, in addition to the typhoon treated in the August bulletin, another one began to influence the Archipelago from the 1st of the month, being found on the 3d east of the Liukiu group; (2) on the 4th there was a depression east of north Luzon, distinct from the previous one and distinct from the one encountered by the steamer *Sumner* near the Island of Kiushiu; (3) the depression felt in the eastern and southern Visayas on the 5th and announced on the 6th was also different from any of the others. This is proved by comparisons of the barometric minima and the atmospheric currents. Moreover on the 6th, when the Japanese typhoon was still east of the Liukiu group, the barometric minimum was registered in eastern Samar and in Luzon. From the 6th to the 9th the vortex moved north, north-northeast, and northeast, and only began to affect the Liukiu group on the morning of the 10th, moving away to the northeast on the same day without affecting Japan, as may be seen from the meteorological notes from that region. It follows, then, that during the early part of September, in the short space of six days, five typhoons passed over various regions of the extreme east, some of them, like the one described last month and the one that entered Japan near Kiushiu Island, perfectly developed.

Bifurcation of cyclones.—It happens now and then that, owing to topographical conditions or climatological influences or for some other unknown reason, a cyclonic vortex, to all appearances, divides itself, the two new centers thus formed advancing along distinct trajectories. Thus it becomes a case of simultaneous cyclones. A very remarkable instance was the bifurcation of the typhoon of September 15 and 16, 1894. It took place in the interior of Luzon and will be found fully discussed in "Baguios ó Tifones de 1894" (pp. 69–71). It is possible that this was simply a particular case of the formation of a secondary cyclone. But there are instances in which the two vortices formed two independent, completely developed storm bodies, which does not happen in the case of secondary cyclones, since these always remain within the storm field of the principal nucleus.

Secondary cyclones.—It is now generally admitted that within the region of a cyclone small centers with a system of cyclonic currents of their own can and sometimes do develop, influencing the isobars and diverting the currents from their normal directions, with the result that far away from the principal vortex violent and destructive winds are experienced. Such centers are called secondary cyclones.[2] Typhoons of this description have been repeatedly observed in the Archipelago, a notable instance being the secondary cyclone which developed in the Bay of Balayan (Batangas) while a cyclone was moving across central Luzon in September, 1894.

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[1] Philippine Weather Bureau, September, 1902, p. 199. [2] "A Popular Treatise on the Winds," p. 315.

Cyclones which disappear within the zone of the Archipelago.—This phenomenon has taken place several times, mocking the warnings of the careful forecaster. Of course this is the least dangerous of all anomalies, except to the reputation of the weather prophet in the eyes of unreasonable people. An experience of this kind we had in the last decade of November, 1897, and several other cases we could cite. But we wish to conclude this chapter, merely remarking that in all cases of apparent anomaly the modifications of the cyclone which are experienced, being due to extrinsic causes, produce only changes in the different currents. These even an isolated observer can easily interpret and even foresee if he has at his disposal the means of detecting the existence and determining the position of the disturbing cause, which is generally another cyclone.

PART IV. NOTES ON CYCLONES OF INTEREST TO THE SAILOR.

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CHAPTER I. A FEW PRACTICAL HINTS TO SAILORS ON CYCLONIC STORMS IN THE PACIFIC AND CHINA SEA AND IN THE SEAS IN AND AROUND THE PHILIPPINE ARCHIPELAGO.

Cyclonic storms and atmospheric perturbances—Preliminary remarks.—There are three kinds of rotatory storms in the Pacific and in the North and South China Seas and in the Philippine Archipelago.

First. Those in which there is a calm center and inner storm area of hurricane winds—e. g., zone D, and an outer storm area of violent winds, say, zone C, and sometimes the zones B and A.

Second. Those in which there is only an imperfect calm center of variable light winds and an inner storm center of strong winds. These winds, though strong and violent, are not of hurricane force, or not exceeding force 10. Outside this center there is another area, usually very large, of strong winds not exceeding the force of a regular gale.

Third. Those in which there is no well-defined central calm and in which the wind does not exceed force 8 and the barometric fall is not large, usually not below 735 millimeters (or 29 inches) in high latitudes and 742 millimeters (or 29.2 inches) in lower parallels.

The first two are commonly called cyclones or cyclonic storms, while the third we call an atmospheric perturbance. The Philippine natives call this class of storm a "colla."

Changes of strength in individual cyclones.—It is to be noted that any individual storm may be found successively in each of the three stages just mentioned, generally beginning with the third and then passing through the second and first. Nevertheless it often happens that when a storm reaches land in a well-developed condition it becomes weakened and falls from the first class to the second and sometimes even to the third. This often takes place when a storm strikes the Asiatic continent, as also when a cyclone from the Pacific reaches the Japanese coast.

The storms usually grow stronger (*a*) with increase of latitude; (*b*) near the coast, before reaching land; or (*c*) while moving over the sea.

We have many instances which confirm what we have just said. Cyclones recurving in the Pacific, east of the Philippines, or east of the Baschi and Balingtan Channels or east of Formosa, are more severe in the second branch of their parabola than in the first. The same cyclones become stronger if they reach Japan before striking the coast.

Cyclones are ordinarily stronger in the China Sea and near the China and Cochin China coasts or in the Gulf of Tonkin than when crossing the islands or close to the west of the Philippines.

Two kinds of cyclonic trajectories.—There are two very decided types of cyclonic storms in the Far East, one crossing the zone of the Archipelago in a westerly direction, the other remaining in the Pacific and ordinarily recurving somewhere between the fourteenth and twenty-fifth parallels.

Storms of the first kind are very rare above the twelfth parallel during the months of December, January, and March; but from the twelfth parallel to the equator they are frequent. On the other hand, these storms are of regular occurrence from the twelfth parallel upward during the months of November, April, and May, frequent during June, July, August, September, and October; while below the twelfth parallel they are fairly frequent during November, April, and May, but less frequent during June, July, August, September, and October. There is always a likelihood of storms of the second kind taking place; though during June, July, August, and September they recurve farther west—that is, approach more the continent.

Storms of either kind are of rare occurrence during February and the beginning of March.

Some very important rules.—The most efficacious means for keeping one from falling into the body of a cyclone is to know for certain and independently of the daily oscillation of the atmosphere when the barometer begins to fall. For this purpose we have compared barometric observations extending over a series of years and have calculated those hours of the day in which the reading of the barometer differs least from the mean reading of each day.

For the zone comprised between the tenth and sixteenth parallels we made use of the table published in Chapter IV of Part I, and for other parts of the Far East we utilized the published hourly observations of other standard observatories, especially those of Japan, Zikawei, and Formosa. From these observations it was easy to interpolate and find the values which we give in the following table:

HOURS AT WHICH THE READING OF THE BAROMETER DIFFERS LEAST FROM THE MEAN READING OF THE DAY.

[Degrees north latitude.]

Month.	10°-16°.			16°-22°.		
January	5.35 a. m.	0.10 p. m.	7.30 p. m.	5.50 a. m.	0.15 p. m.	7.45 p. m.
February	5.20 a. m.	0.20 p. m.	8.00 p. m.	5.35 a. m.	0,30 p. m.	8.10 p. m.
March	5.15 a. m.	0.25 p. m.	8.05 p. m.	5.30 a. m.	0.35 p. m.	8.10 p. m.
April	5.00 a. m.	0.25 p. m.	8.05 p. m.	5.25 a. m.	0.40 p. m.	8.10 p. m.
May	5.05 a. m.	0.10 p. m.	7.45 p. m.	5.30 a. m.	0.45 p. m.	8.00 p. m.
June	5.45 a. m.	Noon.	7.30 p. m.	5.50 a. m.	0.50 p. m.	7.45 p. m.
July	6.00 a. m.	0.10 p. m.	7.30 p. m.	6.05 a. m.	0.50 p. m.	7.50 p. m.
August	6.15 a. m.	0.10 p. m.	7.30 p. m.	6.10 a. m.	0.35 p. m.	7.45 p. m.
September	6.20 a. m.	0.10 p. m.	7.25 p. m.	6.15 a. m.	0.20 p. m.	7.35 p. m.
October	5.45 a. m.	0.05 p. m.	7.15 p. m.	5.50 a. m.	0.15 p. m.	7.25 p. m.
November	5.50 a. m.	0.05 p. m.	7.00 p. m.	5.50 a. m.	0.10 p. m.	7.15 p. m.
December	5.45 a. m.	0.10 p. m.	7.10 p. m.	5.50 a. m.	0.15 p. m.	7.25 p. m.

Month.	22°-24°.			24°-28°.		
January	6.00 a. m.	0.25 p. m.	7.55 p. m.	6.00 a. m.	11.45 a. m.	6.20 p. m.
February	5.50 a. m.	0.55 p. m.	8.25 p. m.	5.30 a. m.	0.10 p. m.	7.45 p. m.
March	6.10 a. m.	0.55 p. m.	8.15 p. m.	5.50 a. m.	0.15 p. m.	7.45 p. m.
April	6.10 a. m.	1.05 p. m.	8.20 p. m.	1.00 a. m.	0.25 p. m.	7.30 p. m.
May	6.00 a. m.	1.15 p. m.	8 25 p. m.	5.35 a. m.	0.20 p. m.	7.30 p. m.
June	6.00 a. m.	1.10 p. m.	8.15 p. m.	5.30 a. m.	0.10 p. m.	7.25 p. m.
July	6.15 a. m.	1.15 p. m.	8.00 p. m.	5.15 a. m.	11.55 a. m.	7.50 p. m.
August	6.20 a. m.	1.00 p. m.	8.00 p. m.	1.40 a. m.	0.10 p. m.	7.40 p. m.
September	6.10 a. m.	0.30 p. m.	7.45 p. m.	5.35 a. m.	0.05 p. m.	7.15 p. m.
October	5.55 a. m.	0.20 p. m.	7.35 p. m.	6.10 a. m.	11.40 a. m.	6.30 p. m.
November	5.50 a. m.	0.15 p. m.	7.30 p. m.	5.50 a. m.	11.45 a. m.	6.30 p. m.
December	5.50 a. m.	0.20 p. m.	7.45 p. m.	1.30 a. m.	11.40 a. m.	6.45 p. m.

Month.	28°-32°.			32°-35°.		
January	6.05 a. m.	11.50 a. m.	7.05 p. m.	2.30 a. m.	Noon.	6.35 p. m.
February	6.05 a. m.	0.20 p. m.	7.45 p. m.	3.20 a. m.	0.05 p. m.	7.35 p. m.
March	6.10 a. m.	0.30 p. m.	8.00 p. m.	2.25 a. m.	0.05 p. m.	7.55 p. m.
April	6.10 a. m.	1.05 p. m.	7.55 p. m.	2.35 a. m.	0.20 p. m.	8.40 p. m.
May	5.40 a. m.	0.50 p. m.	8.05 p. m.	3.00 a. m.	0.20 p. m.	8.35 p. m.
June	5.45 a. m.	0.45 p. m.	7.55 p. m.	2.30 a. m.	0.20 p. m.	8.35 p. m.
July	6.10 a. m.	0.50 p. m.	8.05 p. m.	3.00 a. m.	0.15 p. m.	9.00 p. m.
August	6.10 a. m.	0.45 p. m.	7.45 p. m.	3.00 a. m.	0.05 p. m.	8.25 p. m.
September	6.20 a. m.	0.20 p. m.	7.10 p. m.	2.30 a. m.	11.40 a. m.	7.35 p. m.
October	5.55 a. m.	0.10 p. m.	7.05 p. m.	2.25 a. m.	11.35 a. m.	7.30 p. m.
November	6.05 a. m.	11.50 a. m.	6.55 p. m.	3.30 a. m.	11.45 a. m.	7.00 p. m.
December	6.05 a. m.	11.50 a. m.	7.10 p. m.	3.25 a. m.	11.45 a. m.	7.10 p. m.

HOURS AT WHICH THE READING OF THE BAROMETER DIFFERS LEAST FROM THE MEAN READING OF THE DAY—Continued.

[Degrees north latitude.]

Month.	35°-37°.			37°-40°.	40°-44°.
January	4.00 a. m.	11.10 a. m.	6.40 p. m.	11.00 a. m.	10.45 a. m.
February	2.30 a. m.	11.35 a. m.	7.10 p. m,	11.35 a. m.	11.40 a. m.
March	2.10 a. m.	11.45 a. m.	7.35 p. m.	11.15 a. m.	10.45 a. m.
April	2.00 a. m.	11.50 a. m.	7.10 p. m.	11.25 a. m.	11.00 a. m.
May	2.00 a. m.	11.50 a. m.	8.00 p. m.	11.40 a. m.	11.25 a. m.
June	4.00 a. m.	0.10 p. m.	8.05 p. m.	11.35 a. m.	11.15 a. m.
July	4.10 a. m.	11.50 a. m.	7.40 p. m.	11.50 a. m.	11.55 a. m.
August	4.20 a. m.	11.40 a. m.	7.25 p. m.	11.40 a. m.	11.40 a. m.
September	5.00 a. m.	11.35 a. m.	7.05 p. m.	11.35 a. m.	11.35 a. m.
October	4.35 a. m.	11.20 a. m.	6.40 p. m.	11.15 a. m.	11.00 a. m.
November	4.30 a. m.	11.15 a. m.	6.40 p. m.	11.00 a. m.	10.40 a. m.
December	4.50 a. m.	11.20 a. m.	6.30 p. m.	10.50 a. m.	10.25 a. m.

The following practical rules, whose importance we can not sufficiently recommend to the sailor, are deduced from the preceding table:

First. From the tenth to the twenty-fourth parallel—that is to say, in the Tropics—on account of the oscillations of the barometer being more regular, the hours in which the reading of the barometer approaches the mean pressure vary but little from one month to another. Still, as the barometric oscillation in that region is so great, the reading of the barometer may vary sensibly in the space of ten minutes even in normal weather; consequently the barometer ought to be read as near as possible to the times given in the table.

Second. Outside the Tropics the error will not be so great by reading the barometer a few minutes before or after the times given in the table.

Third. The three daily readings given in the table for parallels between 10° and 37° may be compared among themselves, and if it is observed that the reading during the day decreases, although not more than half a millimeter, we may be certain that the barometer is falling.

Fourth. If the readings of one day are compared with the corresponding ones of the other day and it is noticed that the reading is decreasing we may again be certain that the pressure is falling. This rule is much more sure than the foregoing one, and in both cases the absolute fall of the barometer may be known quite independently of the diurnal or nocturnal oscillation.

Fifth. From the twenty-fourth to the forty-fourth parallel the barometric oscillation is somewhat irregular, and this irregularity increases with the latitude, at least as far as the forty-fifth, and consequently we only give one point of reference, which for latitudes 37° to 44° is near noon.

DIFFERENT CONDITIONS IN DIFFERENT DISTRICTS RESPECTING THE OCCURRENCE OF CYCLONIC STORMS.

As the foregoing notes show, and as may be deduced from Chapters VII and VIII of Part I of this work, there is a great variety in the trajectories and occurrence of cyclones with respect to the different parts of the Far East. There are four districts to be considered, which we may group into southern and northern, eastern, and western. The north districts are separated from those of the south by the twelfth parallel, and the east districts from the west ones in the south by the meridian 123° 30′ E. and in the north by the meridian 122° E., as may be seen on the maps of Chapter X of Part I. (See Pls. XVII–XXIX.)

These districts are therefore identical with the meteorological districts into which we consider the Archipelago as being divided. The south districts are, respectively, Districts I and II and the north Districts III and IV. I and III are the eastern, I and IV the western districts.

We will show what kind of weather a sailor may expect in each of these districts during the different groups of months in which we consider the year as being divided.

FIRST GROUP—DECEMBER, JANUARY, FEBRUARY, AND MARCH.

Districts I and II.—The northeast monsoon is not so strong in these districts as it is in those of the north, although the atmospheric perturbances, and even the cyclones of the second kind above described, which run from the eastern Carolines as far as Mindanao and the Jolo Sea, are not uncommon. If these cyclones reach the first class, which very rarely happens, they are of very small diameter and belong to type 8 (Pl. XXV, Chap. X, Part I). Cyclones of type 1 may be also met with between the east and west Carolines, and those of type 9 closer to the Archipelago. The existence of these cyclones may be known by means of the ordinary signs. In general we may say that when the monsoon increases considerably above the sixth parallel of north latitude, or when the winds from east to north tend to freshen, without any increase of pressure, but with a steady or falling barometer, we may be certain that some atmospheric perturbation is passing or will pass by very low parallels. When this happens the currents in the Surigao Strait are very strong, and navigation is very dangerous for small boats close to the eastern coasts of Mindanao and even more so in the Jolo Sea, and the south of the China Sea.

If the winds from the north to east freshen, with a rising barometer, it is a sign of an increase of the monsoon owing to the extraordinary rise of pressure in the northern regions. In this case also, it is generally dangerous for small boats close to the eastern coasts of Mindanao, south of Cape San Agustin where the currents are very strong, as also in the Surigao Strait. Navigation in the south of the China Sea is not so exposed to danger as in the preceding case. If, while navigating close to the group of the western Carolines, it is judged by the ordinary signs that there exists an atmospheric perturbance, great care must be taken in observing whether the wind currents or lower clouds veer to the northwest or west with a fall of the barometer; for, in such a case, it may be taken for certain that a cyclone of type 1 or 3 is crossing that sea, so that if we are sailing toward the east it will be necessary to modify somewhat the course if the barometer remains stationary, or to deviate somewhat to the southeast if the barometer falls. We must do the same if the wind remains stationary in the west, which is a sign that the cyclone is recurving, or if it tends to veer to the south, a sign that the cyclone is going to pass by the north.

But if the sailor is going toward the Philippines and the wind is backing to the west with a falling barometer, it is always a good precaution to deviate toward the south, or to continue in a westerly direction if the pressure is not decreasing. In all these cases it is of prime importance to determine the direction of the swell.

District III.—In this district the north monsoon is much stronger than in the two preceding. The cyclones of type 1 at a distance from the Archipelago, or types 2 and 3 close to the Philippines, are not to be feared. When noticing the existence of any cyclone in this district during the months of the first group it ought to be borne in mind that the vortex either recurves in the Pacific or goes along with a great inclination to the north, so that it is always a good precaution to navigate in a path inclined to the south except when it is certain that the cyclone is not recurving, since in this case, if going to the Philippines, the path to the west may be continued; but if proceeding to America it will be necessary to modify the course if the barometer falls.

The recurving of a cyclone ordinarily does not take place higher than the twenty-fifth parallel of north latitude, so that if sailing in latitudes higher than the twenty-third the existence of some cyclone is noted it may be taken for certain that the trajectory is the second branch of the parabola, if the ship is at a distance from Japan; if close to that group of islands it may also be some atmospheric perturbation (winter storm) which seldom exceeds the second class of rotatory storms and generally travels to Japan from the Asiatic continent. In both cases the vortex moves toward some point between the north and east. These cyclones are the more to be feared the higher the latitudes are in which they move and the farther away they are from the Asiatic continent. It is to be noted that when a cyclone crosses by very low parallels and when the monsoon increases, owing to the pressure being very high in the north of the continent, navigation east of the Baschi Strait, east of Luzon, and the Strait of San Bernardino is much more dangerous, especially in smaller boats.

District IV.—This district is almost free of cyclones during the months of the first group, though it is not free from the effects of the cyclonic storms which run through Districts I and II, because in such cases the northeast monsoon increases greatly to the north of the Formosa Channel and alters very considerably the tides in the Straits of Baschi and Balingtan. The monsoon is also strengthened when the pressure in the interior of Asia increases and when the barometers are high in Formosa and the neighboring seas.

SECOND GROUP—APRIL, MAY, OCTOBER, AND NOVEMBER.

Districts I and II.—During these months, in which the northeast monsoon does not blow, the general lower currents both in the straits and in the open Pacific are generally from the east to south and increase greatly whenever an atmospheric perturbance crosses between the sixth and twelfth parallels in District I. Atmospheric perturbances are very rare in lower parallels in District I during this group of months, and scarcely ever occur in District II. During April the atmospheric perturbances of type 1 are not uncommon, though they are generally of the third kind. In May those of types 5 and 9 are more frequent, and they generally move in the north of Districts I and II and influence the whole of those zones.

Districts III and IV.—In District III during the months of April and May the only cyclones that are to be feared are those of type 1, which are somewhat rare, and those of types 5 and 9, which are more frequent. It is to be noted that the cyclones of type 9 are dangerous in these districts in the second branch of the parabola, because they are felt twice in the Pacific, once when they run in the first branch of the parabola in the direction west-northwest or northwest and again when they move in the second branch with the direction northeast or north-northeast at a distance from the south coast of Japan.

During the months of October and November, besides the occurrence of some cyclones of types 1, 5, and 9, those of types 6, 7, and 8 are fairly frequent, and they are very dangerous in the Pacific between the tenth and eighteenth parallels and in the China Sea between the eighth and twentieth parallels. During October especially these cyclones sometimes succeed each other at short intervals and have generally very definite characteristics, being usually typical cyclones of the first kind. If the mean tracks of the cyclones just mentioned are known, it will be easy for the sailor to know what means he must take to avoid being caught in these most dangerous of cyclones and to avoid falling into zones B and C of the typhoon, especially if he has plenty of sea room.

THIRD GROUP—JUNE, JULY, AUGUST, AND SEPTEMBER.

According to what we have said in Chapter IX of Part I, we call this part of the year the typhoon season, because it is during these months that the cyclonic storms are the most frequent, especially in District IV or in the portion of the China Sea north of the twelfth parallel.

Districts I and II.—The dangerous typhoons for these districts during the months of the third group are those of types 8 and 9. The other cyclones which cross Districts III and IV have an indirect influence on these zones with the currents proportionate to the distance of the vortex. Very frequently during the months of June and July there are centers of low pressure stationary to the east or to the west of the Baschi and Balingtan Channels, and these influence these districts for several days with rains and currents from south to west-southwest. It sometimes happens that these centers of low pressure are changed into true cyclonic centers of the first or second class; the movement of the barometer will indicate the character of the center. As has been said in Chapter IV of Part II, *the winds from the southwest and in general from the third quadrant are always signs of an atmospheric perturbance of the first, second, or third kind,* there being no southwest monsoon in the Philippines. The case is different with the currents from the northeast during the months of the first group, for these are at times simply the effect of the monsoon, or form the monsoon itself.

Navigation is not generally dangerous in these districts during the months of this group except near the twelfth parallel when a cyclone of types 8, 6, and 6 *a* is passing, and in these cases it is somewhat more dangerous in the first district.

Districts III and IV.—The sailor should always be on his guard in these districts, for the cyclones are not rare during the months of the third group—cyclones of types 2 and 3 especially during August; type 4 during the month of September; type 5 during June; type 6 and 6 *a* during July, August, and September, and types 10 and 11 in July and September. These cyclones generally present themselves with well-defined characteristics, especially in July and September.

During the month of June cyclones of the third kind are very liable to occur, while during June the twin and simultaneous cyclones are very frequent, as was pointed out in the last chapter of Part III. Cyclones of types 2 and 3 are very dangerous for vessels sailing from Japan to Manila, or, vice versa, when passing by the east of Formosa. If while sailing to the south of the twentieth parallel in District III it is noticed that the wind is not only not inclining more to the south but has a tendency to veer to the west, without a decided rise of the barometer, it may be taken as a certain sign that a cyclone to the north of the ship is recurving in the Pacific, and this sign will be confirmed if, while the wind remains steady in the west, the barometer rises. On the other hand, if, while sailing to the north of the twentieth parallel, it is noticed that while the barometer is falling the wind comes steadily from the north without veering to the east, but on the contrary has a tendency to blow from the northwest, it should be taken almost for granted that the cyclone will not pass by the meridian of the vessel but will recurve in the Pacific. In such a case it will be a good precaution to change the course to the southwest, if coming to the Philippines, or to the northwest if going to Japan.

It often happens during these months, especially in July, August, and September, that when sailing, for example, directly from Nagasaki to Hongkong the winds from the east begin to freshen, with a falling barometer. This should always be taken as a sign of a cyclone of type 3; but if the winds from the north freshen, with a falling barometer, it will be a sign of a cyclone of type 2. This second case is not so dangerous, because if with a course toward the southwest or south-southwest it is noticed that the wind from the north has a tendency to back to the west, with a rising barometer, the cyclone will be at a distance to the east and northeast of the ship. The first case, however, is very dangerous because the second branch of the parabola of the cyclones of the third type follows a direction almost contrary to that of the ships sailing in the said route, and consequently it is very easy to be caught in the most terrible part of the storm if the course of the meteor is not carefully noted.

The falling of the barometer, with the wind steady in the east or east-southeast, is a certain indication that the vortex of the cyclone is approaching the boat on a trajectory inclined to the north-northeast or northeast, in which case it will doubtless be a good remedy on the high sea, if the boat is not already in zone C, to alter the course to the south-southwest or southwest, or to incline to the west so as to give room for the center to cross by the south. This will be known if the wind backs to the north or northwest, without the barometer falling much. When the winds have backed to north or northwest the former course may be resumed without much fear of encountering the cyclone.

INDICATION OF THE FORMATION OR THE APPROACH OF A CYCLONIC STORM IN DISTRICTS III AND IV DURING THE MONTHS OF THE FIRST AND SECOND GROUPS, OCTOBER TO MAY.

In Districts I and II below the twelfth parallel the cyclones are either in formation, especially when they stay in District I, or else run with very small velocity, and so we do not give here any special rules for recognizing their formation or approach, as the sailor in those districts may easily recognize them with moderate diligence.

The first indications of the main features of the weather preceding these storms in Districts III and IV are:

(1) Before the formation of a cyclone the atmospheric pressure is somewhat above the normal. This rule refers principally to District III, because there are very few cyclones formed in District IV. It must be noted, nevertheless, that close to the twelfth parallel this rule is not so sure. The farther to the north the greater is the tendency for the barometer to rise at the formation or the approach of a cyclone.

(2) The movement and direction of the higher clouds is a very good sign in the Tropics. We say in the Tropics because this sign is probably not so observable north of the twenty-third parallel.

(3) The winds are light and variable in the Tropics, and the currents from the north and northeast freshen in higher latitudes at the approach of a cyclone, while the currents from north to

east freshen in the whole of the district, after which follow the variations given in the preceding paragraphs.

(4) The cyclonic swell constitutes a most valuable indication of the approach of a cyclone, especially in District III. In the China Sea the swell will indicate the passage of a cyclone by the south, but not so well the movement of the cyclones which remain in the Pacific, especially between the twelfth and twentieth parallels. As a general rule, a strong swell from the east in the inland seas of the Archipelago, in the Jolo Sea, and in the China Sea between the ninth and fifteenth parallels is a sign of a cyclone either recurving in the Pacific between said parallels or crossing the Archipelago by that zone.

INDICATIONS OF THE FORMATION OR OF THE APPROACH OF A CYCLONE DURING THE MONTHS OF THE THIRD GROUP—JUNE TO OCTOBER.

In District I.—(1) A somewhat high, steady barometer, accompanied with frequent rains and calms, will be an indication of the formation of a cyclone.

(2) If besides this the wind freshens at times with gusts of wind from the west to the south, while the barometer has a tendency to fall, it will be a sign that the cyclone is acquiring its movement of translation. The successive changes of the wind and the pressure will indicate the movement of the cyclone, which in this district will not be very dangerous.

In District II.—In June there are cases of the formation of a typhoon in this district which may be recognized from what has been said concerning District I. Outside of this month there is not much likelihood of the formation of a cyclone, though a cyclone may cross by the north, or one of the cyclones which recurve in the Pacific may draw near. In both cases it will be noted that the wind from the third quadrant freshens, and a few squalls occur with a slow fall of the barometer. These cyclones can almost always be known from the persistent convergence of cirro-strati.

In District III.—This district is very dangerous for sailors during these months. Besides what has been said in Nos. 2 and 4, in speaking of the cyclones during the months of the first and second group, the following should be noted:

(1) When the slow fall of the barometer begins at the approach of a cyclone the wind from the third quadrant freshens from the seventeenth and twentieth parallels, and the squalls come on in proportion as the barometer falls. The important and practical point in this district is to know whether the cyclone is one of those which recurve in the Pacific (types 2 or 3) or whether it be one of those which cross the Archipelago or recurve in the China Sea (types 4, 5, 6, 6 *a*, 7, 8, or 9).

(2) It may be established as a general rule that when the barometer falls slowly south of the seventeenth parallel, with winds and squalls from the third quadrant, without the pressure having the marked fall but rather remaining somewhat low for one or more days, the cyclone will be one of types 2 or 3. If there is, however, the marked fall in the atmospheric pressure, it may be feared that the typhoon will be of the types 4, 6, 6 *a*, 7, 8, or 9.

(3) If, while the barometer is falling slowly, it is noted that the wind is very variable north of the seventeenth parallel, and that there are squalls from the north at intervals, the cyclone will probably be one of types 2 or 3. If the barometer continues to fall and the winds from north to east and southeast become fixed it is an indication that the cyclone will cross close to by the south.

(4) When the recurve takes place slowly the fall of the barometer and the veering of the winds will indicate with some certainty when the cyclone is of the types 4, 5, 6, 6 *a*, 7, 8, or 9, in whatever latitude the vessel may be.

(5) The cyclones of the types 2 or 3 move with moderate velocity, and consequently the manner in which the barometer falls, with the veering of the wind, will enable one to recognize them with sufficient clearness.

Bearing of the storm center.—This is the most easily determined with the help of the cyclonometer. (See Chapter VII, Part II.)

The bearing of the center may also be determined without the help of the cyclonometer, especially to the north and west of the center, by the following indication:

(1) When the sky begins to cloud over with cirri the veil of this cloud generally appears densest in some particular point of the horizon, and it frequently happens in the Tropics that the

cirro-strati diverge in feather-like streamers from that point. At other times the cirrus cloud forms a kind of misty cloak which covers the storm or hurricane cloud. The position of this point of radiance or divergence and the misty cloak is sometimes the first indication of the existence and general bearing of the cyclonic storm.

(2) The position of the center of the bank of clouds and the lightning which flashes out almost continually, fixes approximately the bearing of the cyclone. The cloud bank of a cyclone is easily distinguishable from all other cloud masses by the fixity of its position and form, for it retains its form and position unchanged for hours, and it is only when the storm is in the immediate vicinity that it loses its remarkable appearance. As the storm approaches masses of cloud are seen to be torn from it. This indication is mostly observable in the third and fourth districts. In the first and second districts it is not so often observed, because the sky in these zones is more or less heavily clouded, and it is only under exceptional circumstances that the dense, fixed cloud mass of the cyclone storm can be perceived in the distant horizon.

(3) The direction of the swell which is produced by the distant storm and passes out from it gives in many instances a fair indication of the direction of the cyclone, especially in the third district. In the first and second districts the swell passing out from the storm and the swell caused by the strong southerly winds give rise to a heavy cross swell, which is an almost unfailing sign of a cyclonic storm to the north, especially in the first district and in the south China Sea.

(4) Another useful indication for ascertaining the bearing the center of the cyclone is the direction of the squalls. The cumulus cloud of the squall rises toward the zenith, then spreading out and covering the sky. The base of the cloud soon forms above the horizon the dark band which is so characteristic of an approaching squall. The rain comes with this cloud, when the wind freshens and veers to the right. Later on the squalls break from the extreme portion of the cloud bank and follow the general movement of rotation of the storm. If the scud above the cloud bank be watched it will be noticed that it flies nearly parallel to the bank, so that an observer looking at the cloud sees the scud crossing it from left to right. The lower clouds in the interior of the cyclone generally fly to the right of the wind and almost perpendicular to the bearing of the cyclone. It may also be noted that a squall frequently ushers in a shift of the wind and that *the wind during a squall is almost invariably to the right of that prevailing previous to the squall.*

The following additions, taken from Eliot's handbook on cyclones (pp. 303 ff.) and applied to the storms in the Far East, will be found of practical value:

Position of the observer relative to the storm track.—If the bearing of the center remains the same for some time (due to the center advancing directly to the observer) this will be shown by the barometer falling and the wind increasing in strength, while its general direction remains unchanged (although it may shift for a short time in squalls). If the observer be in the storm area to the right or left of the track the wind will shift as the storm advances toward and past him. If the observer be in the dangerous semicircle (as defined above) the wind veers or shifts with the sun through north, east, south, and west, and if it shifts in this manner the observer is to the right of the track. In the manageable semicircle the wind backs or shifts against the sun, or through north, west, south to the east, and if the wind shifts in this manner the observer is to the left of the track or in the manageable semicircle.

Direction of the track or course of the cyclone center.—It is always desirable that the probable track, as well as the bearing of the center of a cyclone, should be determined as early as possible in order to keep as far away from the inner storm area as possible and to bear away from it if the vessel be approaching it. The transition from the outer to the inner storm area is always comparatively sudden, and if the sailor delay in taking stock of the storm he may find himself involved in the inner storm area before he is prepared and when it is too late to do anything. Hence, shortly after the sailor is certain he is involved in the outskirts of a cyclonic storm and is probably passing inwards toward the center, and the wind direction has informed him in which semicircle and quadrant of the storm he is, he should lie to for some time and see whether there is any permanent shift of wind. If he be in the south or southeast portions of the cyclonic storm in which strong squally winds extend to very considerable distances from the storm, it is probable he will observe no permanent change of wind even if he lies to for some hours, and in that case he may conclude he is at a considerable distance to the south. He should, if advancing up north in the Pacific or in the China Sea, either proceed slowly northward or only take advantage of the southerly winds in the easterly quadrant by keeping well to the east of the storm center, and should only adopt that course if he be quite certain the storm is either not a large one or if it is a cyclone that it is advancing westward and there is no chance of its recurving eastward between the eighteenth and twentieth parallels.

If he be in any of the other quadrants of the storm area, and more especially if in the right advancing quadrant, he should lie to until he observes a shift of wind and should also note carefully the weather during this interval. A reference to the cyclonometer arrows (Chapter VI of Part II) will give him at a glance approximately the direction of the path or track of the center.

The inner storm area of the intense cyclones is probably never less than 80 to 100 miles in diameter or greater than 400 or 500 miles. The rate at which the barometer falls, the rapidity with which the wind shifts, together with the force of the wind, and the swell and sky indications will usually tell the sailor whether a cyclone he meets with is a small or a large one and whether he is approaching or entering the inner storm area or is still well outside of it, etc. Combining these facts with the above statement of the limiting magnitudes of the inner storm area of cyclones, he will be able to estimate approximately at what distance he is from the center.

Practical hints for navigating vessels during cyclonic storms.—When the sailor has ascertained the bearing and track of the center of a cyclonic storm he has then to determine what action he will take in order to avoid it so far as possible. The following hints are given chiefly by way of suggestion, and not as rules:

In the case of a steamer there is no doubt that, if the earlier indications of a cyclone be carefully observed and the position and path of the cyclone be judged with approximate correctness, it is nearly always possible to avoid entirely the inner storm area and to pass out or keep outside of the outer storm area.

It would be out of place in the present book to attempt to give precise instructions how to handle a vessel in order to avoid a cyclonic storm or typhoon in the Far East.

In drawing it up, it has been assumed throughout that it is desirable to state and explain every indication by which the bearing, probable distance, and track of the center of a storm can be estimated, and also its intensity, especially so far as it depends upon the month or period of its occurrence. If the sailor has ascertained these points, when he is in the outskirts or outer storm area of a storm he ought to be qualified to decide which is the best course to take in order to avoid, so far as is possible, the chief dangers to which he is exposed; as, for example, passing into the inner storm area, encountering the hurricane winds of a cyclone or the fierce westerly gales of a cyclonic storm of the rains, or of being caried by the wind and currents of an approaching storm against a lee shore.

Much depends upon whether he is in charge of a steamer or a sailing ship, and whether the vessel is large and well found, and also upon his judgment of the position of his vessel with respect to the coast, as well as to the center and upon the strength of the currents produced by the storm.

The object of the sailor ought to be—

First. To avoid entering the inner storm area.

Second. If he finds himself involved in the dangerous semicircle, and more especially in the right advancing quadrant, to use every effort to avoid being carried in front of the advancing center.

He should, as soon as he perceives any indications of a storm, and more especially the occurrence of squalls with increasing frequency and strength, use every available indication to judge of its position and character, and not wait until his barometer begins to fall rapidly and winds have increased to the force of a heavy or hard gale, as he will then almost certainly be entering the inner storm area of a cyclone.

He should, even if in command of a well-found steamer, not attempt to pass round a cyclone in the advancing semicircle unless he has the strongest evidence that the cyclone is at such a distance that he can get well into the left advancing quadrant or manageable semicircle before the inner storm area reaches him. It is always attended with risk, and cyclones north of the third and fourth zones are sometimes of very small diameter and advance very rapidly, if not recurving, so that errors of judgment in the distance of a cyclone are very possible. A ship ought on no account attempt it, except as a last resort.

Hence the advisability that steamers and ships about to proceed to sea from the China coast between the twentieth and thirty-second parallels when a storm is in the Pacific east of the Philippines or southeast of Liu-kiu group, in July, August, and September should delay their voyage until the cyclonic storm has reached land or recurved to the east.

In all cases a ship or steamer should be maneuvered so as to increase her distance from the center as soon as she enters the outer storm area. A steamer can, of course, except under very unusual circumstances, do this if the storm center and track be ascertained early and she have sea room.

CHAPTER II. GENERAL CHARACTER OF THE CYCLONES WHICH HAVE CROSSED BY THE NORTH, SOUTH, EAST, AND WEST OF MANILA.[1]

In this chapter we propose to make a résumé of the whole of Part III of the book, that sailors may have all the information therein contained in a comparatively short space.

DIVISION OF CYCLONES INTO FIVE MAIN GROUPS ACCORDING TO THE POSITION OF THEIR PATHS WITH RESPECT TO MANILA.

We shall consider cyclones divided into five main groups, each one having typical and special characteristics well worth being studied.

First group.—Character of those cyclones which cross to the north of Manila.—These are the cyclones most dangerous to Manila if they cross the Island of Luzon not far from the capital. The winds blow from north to northwest and from west to southwest, so that the vortex approaches our meridian with gradually increasing intensity; in general the most violent winds are from the west-southwest and southwest. After the cyclone has crossed to the north in the direction of the China Sea the wind gradually decreases in force but continues to blow from the south-southwest and south, and even from southeast in those cases where the storm is sufficiently inclined to the west. If the minimum distance of the vortex from Manila is not less than 60 miles the winds will scarcely reach a greater force than 9 or 10 of the Beaufort scale. If the least distance is less than 180 miles the influence of the cyclone upon Manila usually lasts not more than two days. But if it moves through higher latitudes—for instance, through the Baschi and Balingtan Channels or near the Island of Formosa—then, even though the cyclone is to the northeast in the Pacific, strong winds from west-southwest and southwest quickly appear; these, being accompanied by squalls at intervals, cause the bad weather to continue for three or four consecutive days.

Second group.—Character of those cyclones which cross to the south of Manila.—It is worthy of notice, and all who have lived in Manila for some years have undoubtedly noticed it, that a striking difference is observed when a comparison is made of the influence exerted on Manila by a cyclone passing to the north and that exerted by one crossing to the south, although the minimum distance of both may be the same. The first are felt with much greater intensity than the second, not alone when the distances are equal but also when the distance of the latter is much less. Thus, speaking in general, it may be said: First, that a cyclone which crossed south of the meridian of Manila at a distance of from 10 to 60 miles exercised the same influence on the capital as another which crossed to the north at a distance of from 60 to 400 miles; second, that those which cross to the south at a distance of from 60 to 150 miles have much less influence than those which cross to the north at a distance of from 400 to 700 miles. So great is this influence that for cyclones which are more than 400 miles distant, like that of August 6 to 9, 1897, which crossed the meridian of Manila north of Formosa, it was necessary in this port to show the second storm signal, while for those which crossed to the south not more than 120 miles away the winds of the second quadrant rarely if ever acquired sufficient force to cause the Observatory to show any signal whatever. The causes of these facts we believe to be two: First, that the cyclones which move from west to west-northwest along parallels lower than the fifteenth are indeed generally intense, but only in the vicinity of the vortex, the inner storm area being very much reduced in diameter; those which run farther to the north are in general of much larger dimensions, increasing in size with the latitude. And second, that the winds from the northeast and southeast which blow in Manila when a cyclone passes by the south, are impeded by the great mountain ranges, while those from the west-southwest and the southwest strike the Bay of Manila without encountering any obstacle.

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[1] Taken from "Climatologia en el Archipiélago Filipino."

Third group.—Character of those cyclones which recurve in the Pacific without crossing the meridian of Manila.—The effect of these cyclones in Manila is similar to that produced by those which cross to the north some distance away, with the single difference that the strong wind and wind-and-rain squalls from the third quadrant continue at times for five or six days.

The intensity of these rains is naturally so much the greater as the distance which separates the vortex from the Island of Luzon decreases. If this distance is more than 700 miles its influence is scarcely felt in Manila, except for the greater constancy of the winds which blow from the west-southwest and southwest. These blow even outside of the regular hours for the breezes, as happened in the cyclone of September 6 to 9, 1897, and in that which raged at Kobe on August 15 of the year 1899.

Fourth group—Character of those cyclones which form in the China Sea to the west of the Archipelago.—These cyclones are those which are felt least in Manila. As a general rule they move from the point of their formation toward the fourth quadrant and most commonly toward the northwest or west-northwest. They, therefore, recede from the Archipelago and influence Manila only by showers and light or fresh breezes from the south to the southeast.

Although not frequent, cyclones are occasionally felt which, forming in the China Sea, move to the east and northeast passing thus to the north of Manila. When this happens their influence is prolonged for some days, the winds veering from southeast to south and southwest as the vortex advances toward the northeast.

Fifth group—Character of those cyclones which recurve in the China Sea between the tenth and twentieth parallels, passing first to the south and afterwards to the north of Manila.—The influence of these cyclones, especially if they do not go far into the China Sea before recurving, is usually prolonged for six to eight days, being accompanied at first by continuous rains and fresh winds which veer from north to northeast, east, and east-southeast, while the vortex crosses to the south and passes into the China Sea. During the recurve the velocity of the storm usually diminishes notably, rains and fresh breezes continuing at Manila. These breezes from the east-southeast veer to the southeast and south-southeast very slowly. When at the end of three, four, or five days the cyclone has completed the curve it quickly continues its course to the north-northeast, northeast, or east-northeast. This change of position of the vortex, if the cyclone is not too far distant from Manila, is accompanied here by a rapid veering of the winds from the south-southeast to the south-southwest, southwest, west-southwest, and west, these increasing in force till the cyclone has a second time crossed the meridian of Manila to the north. To this class belonged the *Gravina* cyclone (so called because of the wreck of this merchantman near the coast of Zambales) of May 8 to 14, 1895, and the cyclone of Iloilo and Vigan of May 9 to 17, 1896. The vortex of this typhoon passed Iloilo during the first part of its parabolic path and touched Vigan, when, after recurving, it crossed the northwestern extremity of Luzon moving to the northeast. The paths of these two cyclones and others similar to them may be seen on Plate XXVI. (See Part I, Chapter X.)

Thus, knowing in general the influence which a cyclone may have on Manila according as it belongs to one or other of these five groups, it is easy to see that it will be useful to know the months in which the cyclones of these different groups occur. For this purpose we have prepared the following table:

Direction.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Per cent.
North of Manila	------	------	------	------	3	5	32	26	29	20	6	------	121	30
South of Manila	4	------	------	5	9	5	7	6	6	13	19	11	85	21
East of one hundred and twenty-first meridian	2	------	2	3	6	12	14	24	33	11	11	6	124	31
West of Archipelago	------	------	------	1	2	12	13	7	11	10	2	------	58	15
First south, then north of Manila	------	------	1	------	4	1	------	------	------	------	2	1	9	2

Relative frequency of cyclones of each one of these five groups.—According to these data those cyclones which cross the north of Manila and those which remain in the Pacific east of the one hundred and twenty-first meridian east of Greenwich are most frequent. Those which cross the south of Manila are less frequent, while those formed west of the one hundred and twenty-first meridian are still less frequent. Those cyclones which recurve in the China Sea between the tenth and twentieth parallels crossing first to the south and then to the north of Manila occur, as will be seen from the table, but rarely.

Monthly distribution.—In regard to the monthly distribution of the cyclones of these five groups it is evident, first, that those which cross to the north of Manila are more frequent in the months of September, July, August, and October, though they sometimes occur in the months of November, May, and June, but never during the rest of the year; second, that those which cross to the south are most common in November, October, May, and December, and are rarely seen in April, June, July, August, September, and January; third, that those which recurve in the Pacific to the east of the one hundred and twenty-first meridian are very frequent in September, quite frequent in August and July, less so in June, October, and November, and rare in the other months; fourth, that those formed in the China Sea to the west of the one hundred and twenty-first meridian are fairly frequent from June to October, inclusive, in descending grade through June, July, and August and ascending from August to October, the maximum being in the months of June and July, this being the so-called typhoon or cyclone season. Very few have been observed in May, November, and April, and none in the other months; fifth, that of the first group of cyclones but nine have been registered in the period under discussion—one in March, one in June, one in December, two in November, and four in May—they being peculiar therefore to this last month. Thus in the year 1899 we observed a cyclone of this group, from the 18th to the 28th of May, which first crossed the Visayan Islands, being severely felt in Iloilo and Cebu on the 20th and the 21st. It then recurved in the China Sea to the south of Hongkong, between the seventeenth and twentieth parallels, and was lost in the Pacific Ocean to the north of Formosa. Its path may be seen on Plate XXVI.

CHAPTER III. HARBORS OF REFUGE IN THE FAR EAST, ESPECIALLY IN THE PHILIPPINE ARCHIPELAGO.

A. HARBORS OF REFUGE ALONG THE CHINESE COAST.

Backli Bay (19° 7′ N.; 108° 39′ E.), with shelter against winds between north-northeast and south only. It is not a very good harbor.

In southern Hainan **Yulikan Bay** (18° 12′; 109° 33′); an excellent typhoon harbor in case the center is to the south of Hainan, as often happens.

Gaalong Bay (18° 13′; 109° 34′) may also be used.

Maniu Harbor (19° 57′; 109° 52′) can be used when the center is to the north of Hainan.

Hunghom Bay (20° 17′; 110° 23′) is shallow and is not often used except when no better place is within reach.

Hai-ling-san (21° 34′; 111° 47′) and **Namo Harbor** (21° 35′; 112° 34′) are available between Hainan and Hongkong. Near Hongkong is the excellent harbor by **Saint Johns Island** (21° 40′; 112° 42′), which is commonly used. Vessels of great draft anchor to the south of the position given.

Tongku Harbor (22° 35′; 113° 55′) is used in case of typhoons crossing the China Sea. It offers no shelter against west winds. This is at the mouth of the Canton River. Higher up the river ships anchor under the Bogue forts, although typhoon centers pass over that spot, but then it does not blow so hard as out at sea, when the center is inland.

Inside the Capsingmoon Pass to the west of Mahwan is shelter against typhoons, but **Chingwan Bay** (22° 22′; 114° 6½′) is one of the best harbors in China. In consequence it is too crowded during a typhoon.

To the northwest of **Stonecutters Island** (22° 20′; 114° 8′) launches find shelter.

Tijtam Bay to the south of Hongkong is an excellent harbor. **Deep Bay** (22° 17½′; 114° 16′) gives better shepter than **Kowloon Bay** (22° 18½′; 114° 13′), but some vessels prefer the latter, as the storm signals can be seen from there.

A position between Faipintong and the Channel Rocks makes the best anchorage.

Mirs Bay (22° 33½′; 114° 27′), under Pengchaw, offers shelter to vessels bound for Hongkong, from a northern port. Between Mirs Bay and Swatow there are no very good typhoon harbors, but shelter may be found against northeast winds.

By **Namoa Island** (23° 28′; 116° 57′) is excellent anchorage.

Tongsang Harbor (23° 47′; 117° 35′) is much used, and also **Amoy Harbor.**

Makung Harbor (23° 32′; 119° 33′), by the Pescadores, is excellent.

In **Pihquan Harbor** (27° 10′; 120° 31′) there is good shelter against northeast wind to vessels under 15 feet draft.

The **Haitan Straits** (25° 26′; 119° 44′) are very much used.

B. HARBORS OF REFUGE IN THE PHILIPPINE ARCHIPELAGO.[1]

Port San Vicente (18° 30′ N.; 122° 5′ E.), as a place of refuge for vessels during typhoon weather, is the best harbor in northern Luzon, and, in fact, the only thoroughly protected one. It is also resorted to by vessels bound to Aparri when the bar at the mouth of the Cagayan River is too rough to be crossed. Vessels of any size should not attempt to enter this harbor from the eastward, as the rocks and shoals on that side make it dangerous to do so. The entrance from the westward may, however, be made without difficulty. If bound from the northward a vessel should not skirt the Palaui Island too closely; pass Puerto Point about three-fourths of a mile to the southward of it, then head east until nearly south of San Vicente Island, when Rona Island and Escucha Island will be seen through the eastern entrance to the harbor. Puerto Point is a high, wooded bluff at the southwest end of Palaui Island; Rona Island is a low, wooded island with a white base of sand and rocks, and Escucha Island is high and wooded beyond Rona Island when seen from the southwestward. There is good anchorage in the outer harbor, with Puerto Point bearing N. 83° W. and Rona and Escucha Islands in range bearing N. 36° E. in about 7 fathoms, muddy bottom. This berth is exposed to west and southwest winds. There is foul ground from west to east between Puerto Point and the south end of San Vicente Island. The shoal described as Trueno Shoal in the sailing directions and on the charts as Laja Trueno is believed not to exist, as the steamer captains using this harbor say that they have never seen it, and the U. S. S. *Wheeling* passed over its supposed position and saw no sign of it.

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[1] The descriptions are taken mostly from "Derrotero del Archipiélago Filipino, 1879," and from the bulletins compiled at the Coast and Geodetic Survey suboffice, Manila.

Port Bolinao (16° 25′ N.; 119° 55′ E.), on the northern part of the cape, is the most westerly port in Lingayen Gulf and is commercially of little importance. The harbor is formed by a strait between Santiago Island and Cape Bolinao. Silaqui Island, lying about 1 mile north of Santiago Island, is surrounded by reefs and must be given a good berth. The principal value of this port is as a harbor of refuge, it being a perfect typhoon harbor for a small vessel, and the only one on the coast between Cape Engaño and Subic Bay. The entrance is formed by a break in the coral reef, which extends 1 mile off shore north of the town and about 2 miles north of Santiago Island. In heavy weather there is an area of heavy seas about 6 miles northwest by north of the entrance to Bolinao, which area has not been investigated.

Port Matalvi (15° 30′ N.; 119° 56′ E.) is a long, narrow body of water between Matalvi Island (Pulo San Salvador) and the land to the southward and has a mean breadth of about one-half mile. It is rather difficult of access, but a vessel once inside has good anchorage in 7 to 10 fathoms, mud, and perfect protection from all winds.

Subic Bay (14° 53′ N.; 120° 12′ E.) includes the excellent harbors of Subic and Olongapo. The entrance is divided into two channels by Grande Island and a smaller island lying to the southward of it. These islands are surrounded by foul ground and banks for about one-fourth mile, and should be given a berth of one-half mile. The channel west of Grande Island is the more desirable for a stranger, being wide and deep. The western shore is bold and may be approached to one-fourth mile. After passing Grande Island in nearly mid-channel, Pequeña Island will be seen bearing about N. 11° E., and Mayanga Island open to the eastward of it.

Port Olongapo (14° 48′ N.; 120° 16′ E.) is situated on the eastern side of Subic Bay and includes an inner and outer harbor. If bound to Olongapo and having passed the western side of Grande Island in mid-channel, when abreast of the northern end of the island bring the beacon on Calaclan Point to bear northeast and steer for it. A mark has been placed on Calaclan Point to enable it to be readily identified, consisting of a wooden frame in the form of a six-pointed star, 8 feet 10 inches in diameter and painted white, with a center of a black six-pointed star 3 feet 4 inches in diameter. The center is 7 feet above the crown of the hill, or the highest part of Calaclan Point. Hold this course, taking care not to bring the leading mark anything to the northward of NE., until the Cubi Shoal is passed. This line clears the northwest end of Cubi Shoal, marked by a red buoy, by about one-half mile, and also passes about the same distance of a small, unnamed coral patch, with 3 fathoms of water in it, lying 1 mile west-northwest from Pamocan Point. When Nacaban Point bears S. 62° E. a large, conspicuous white mass of rock on the face of the bluff known as Mancha Blanca will be seen opening to the eastward of the Point. The vessel will then be clear of the northern edge of Cubi Shoal, and when Mancha Blanca is well open of Nacaban Point the course may be altered to the eastward to enter the port.

Port Mariveles (14° 26′ N.; 120° 29′ E.) is located on the northwest side of the entrance to Manila Bay and is about northwest by west from Corregidor Island. The harbor is about 1¾ miles long and 1¼ miles wide, and on the southwest and northeast sides the shore is very abrupt. The harbor is free from danger except on the north side, where the 4-fathom curve is about one-fourth mile off shore, and Guardia Shoal, on the west side of the entrance. The quarantine station for Manila is located in the northwest part of the harbor and has a wharf with 25 to 28 feet of water alongside. Fresh water can be procured here. Mariveles is an excellent harbor, easy of access, and affords good shelter. The soundings decrease regularly from 18 fathoms at the entrance to 10 fathoms at the head of the harbor.

Port Maricaban (13° 41′ N.; 120° 50′ E.) is formed by the strait between Caban Island and Maricaban and can be entered from either end, but the passage from the northward is preferable. The water is very deep, and vessels can tie up to the beach on the southwest side of Caban Island. This is not a good harbor for a vessel of any size, and it is of no value unless it could be utilized as a harbor of refuge.

Port Galera (13° 31′ N.; 120° 57′ E.) is formed by a promontory from the coast of Mindoro and the islets Medio and Paniquian, situated to the westward of the promontory. The port is a sort of canal with two passages, one to the northward and the other to the northwest, the opening between Paniquian and the coast not being navigable. The flood stream passes into the port by the northwest channel and out by the north channel and then follows to the eastward, the reverse taking place with the ebb stream. This fact should be remembered in making the port.

Banalacan Port (or **San Andres**) (13° 32′ N.; 121° 52′ E.), Island of Marinduque, is surrounded by high, wooded land, and vessels can lie inside in security. The anchorage is confined, but the depth is good, 10 to 12 fathoms, mud; there is an inner harbor, which can be entered by towing or warping through a narrow passage, about 75 yards wide, there being an islet on the east side of the narrowest part of the channel, which should be passed close to. The inner basin is three-fourths of a mile in extent, and of 5½ to 8 fathoms depth, muddy bottom. A vessel would find herself not only sheltered in it from all winds, but completely hidden, for it is entirely closed in, and its existence would not be suspected without previous knowledge.

Port Busin (13° 8′ N.; 122° 58′ E.) is formed by a channel 3½ miles long and one-eighth of a mile wide in the narrowest part, between Busin and Burias islands. The western entrance is narrow and crooked and very dangerous for a sailing vessel. The northern entrance is preferable, being straight, and its banks are steep-to. The northern entrance may be easily recognized by Colorada Point, the north cape of Burias, which is higher than Busin Island, and shows yellow patches among the trees that cover it. The part of the coast near the entrance may also be known by the massive bluffs. To enter, round Colorada Point at a distance of one-fourth mile and steer down in mid-channel, and the best anchorage will be found off Port San Pascual, with the eastern part of Busin Island bearing N. 28° E. and the south side of the small islet to the southward of Busin bearing S. 70° W., in about 11 fathoms, mud; small craft could go farther into the bay toward the town. Fresh water can be obtained here.

Port Busainga (13° 8′ N.; 123° 2′ E.), Island of Burias, is an inlet 1½ miles long and 200 yards wide, including some bays which afford good shelter from wind and sea. The Boca Islets lie about one-third of a mile N. 56° E. from Piedras Point, and the bottom is foul between them and the shore. To enter, bring Piedras Point to bear west and steer for it; pass about 100 yards from the point and enter the port, keeping in about mid-channel and anchoring with the middle of Medio Island bearing west, and Piedras Point in range with North Point on the north end of the island northeast of Medio Island, bearing N. 30° E., in 10 or 11 fathoms of water, good holding ground. It is high water full and change at $0^h\ 30^m$. Springs rise 5½ feet.

Port Sorsogon (12° 55′ N.; 123° 55′ E.) is the largest and best harbor in southern Luzon and is a good refuge in case of a typhoon or colla and for effecting repairs. The entrance is divided into three channels by the Islands Malumahuan and Bagatao. The channel between these two islands is the only practicable one for vessels, the others, between the islands and the coast, being narrow and shoal.

Port Barrera (12° 32′ N.; 123° 22′ E.), Island of Masbate, 9 miles east-southeast from Bugui Point, is capacious, with a good holding ground. The surrounding land is mountainous, of a red color, and furnishes good wood for building; the shores are covered with mangroves to the water's edge. Colorada Point, the western entrance point, may be recognized by its red cliffs; a ledge of rocks projects 600 yards to the eastward of the point, with 4½ fathoms at its edge. Catbatan Point, on the eastern side of the entrance, has a reef extending 400 yards, with a prominent rock on its extremity. The depth of water in the middle of the port is 16 to 30 fathoms, bottom, coarse sand, but it decreases to the westward and becomes rocky; reefs extend to ¾ mile from the western and northwestern side of the port. On the south side a branch of the port, into which a river enters, penetrates 2 miles inland and offers well-protected anchorage for small vessels, care being taken to avoid a small reef lying about 600 yards off Amoron Point on the eastern side of the channel. The town of Aroroy is near the eastern entrance point. There is good anchorage in 22 fathoms, coarse sand and mud, off the inner side of the sand beach of Colorada Point, which is steep-to, and also in the entrance of the port, with the point bearing north, in 24 fathoms. There is no convenient watering place on the shores of the port; water may be procured from up the river or from the cascade near the mouth of the Lumuclue River in the western part of the port.

Port Magdalena (12° 27′ N.; 123° 32′ E.), Island of Masbate, situated 9 miles southeast of Port Barrera, is very small and open to the northward, but it is considered an excellent anchorage, safe at all seasons. Vessels can secure with hawsers to the trees of the inner part of the port. The anchorage is surrounded by high land covered with impenetrable woods. There are reefs around both exterior points. The depth of water at the entrance is 20 fathoms, decreasing to 3½ fathoms before the village at the bottom of the port, where there are some shoals near the beach.

Port Palanog (Masbate) (12° 22′ N.; 123° 36′ E.), is small, deep, and well sheltered from all winds. The entrance channel is only about 300 yards wide, and great care must be taken to clear the reefs on both sides, specially that from the southeast point, which extends to the middle of the entrance. In entering the port, bring the western entrance to bear about S. 45° W. and steer for it, giving it a berth of about 150 yards in passing, and when the wharf is abeam haul to the southward and eastward and anchor off the town on the east side of the port, in 17 fathoms of water about 500 yards from the beach, with the church bearing about east. There are reefs along the northern and western shores of the port, extending out in places ½ mile.

The wreck of a steam vessel, about 150 feet long, lies off the end of the pier in 13 fathoms of water, with 9 fathoms of water over it. The wreck heads N. 67° E., and its nearest point is S. 60° W., 50 yards distant from the end of the pier. Maximum rise and fall of tide, 6 feet; common establishment of the port, 11^h.

Port Cataingan (11° 58′ N.; 124° 1′ E.), Island of Masbate, about 20 miles south and east of Vigia Point, is a clean and capacious harbor open to the southeast, of good depth of water and good holding ground; it is 1¼ miles wide at the entrance and extends 4½ miles northwesterly in the direction of the Tetas de Cataingan, two prominent round hills at the head of the port. On the eastern side of the long peninsula which forms the port the 5-fathom curve of soundings is about ½ mile from the coast.

The Libucan Islands are a group of three islands and several smaller islets lying about 4 miles off the west coast of Samar.

Libucan Daco (11° 54′ N.; 124° 38′ E.), the largest of the group, is of very irregular shape, 2¼ miles northwest and southeast, and rises to a height of 554 feet. There is good anchorage in a bay on the north side of the island, in 12 fathoms of water, and vessels on the coast make for this anchorage when the southwest gales, called "collas," begin to blow. Two islets named Layalaya, united by a reef which dries at low water, lie 1 mile S. 45° E. from Libucan Daco.

Canahauan Islands (11° 50′ N.; 124° 41′ E.) are a group of two large islands and several smaller ones, lying about 4 miles from the coast of Samar. The Canahauan Islands offer good anchorage among them, sheltered from all winds, that of Port Aguirre affording excellent refuge to a vessel during typhoon weather. As these islands lie 12 miles from Catbalogan and 15 miles from Calbayog, both towns on an open coast, this anchorage offers safe refuge for both. The anchorage area is very small, being about 400 yards in diameter, and the channel approaching it is narrow and crooked. By the channel entering from the eastward it has been reported that there is not less than 14 fathoms (although the chart shows 7 fathoms) until the center of the port is reached, where there is a depth of 9 to 11 fathoms. The U. S. S. *Panay* found it practicable to enter from the southward leaving Batgongon Island on the starboard hand with nearly a straight course and nothing less than 7 fathoms. Close to the south shore of Canahauan Daco, and between it and the small islet to the southward where the chart shows shoal water, the least water found was 4 fathoms, thus permitting small craft to run directly in an emergency. The least water found in the northern entrance was 3½ fathoms at about half tide. Large vessels may find protected anchorage between Canahauan Daco and Batgongon Islands in 15 or 16 fathoms, mud bottom, care being taken in entering to avoid a small shoal patch with 3¼ fathoms on it, lying about ½ mile west of the south end of Boloang Island, the most eastern island of the group. The passages between the islands and banks that compose this group are safe and deep and afford easy access to the anchorages among them, which is an important fact, as there are no protected harbors on the neighboring coasts. The eastern summit of Canahauan Daco is 446 feet high, that of Timpasan, the southwest island, 489 feet, and the others rise between 200 and 400 feet.

Parasan Harbor (11° 42′ N.; 124° 45′ E.), on the south side of the island of the same name, is a small, well-sheltered anchorage in 16 fathoms, mud bottom. This anchorage can be easily approached from the southeast; the northern entrance is only about 75 yards wide, with a least depth of 17 feet and 24 feet in the narrowest place. This anchorage is used as a refuge in typhoon weather by vessels from Catbalogan.

Tacloban (11° 15′ N.; 124° 59′ E.), the capital and largest town in Leyte, is situated on the west side of a peninsula facing the southern entrance to San Juanico Strait. There are five wharves, with 15 to 18 feet of water alongside of two of them. Fresh water, ship's supplies, and coal are not obtainable. Vessels drawing 18 feet can enter the harbor from the southward, but larger vessels are obliged to bring up between Cataisan Point and Dio Island in 5 fathoms, muddy bottom. The usual anchorage in the harbor is 300 to 400 yards to the north and northwest of the town, although the deep water is found farther north. Pilots for Tacloban and San Juanico Strait may be obtained at Jinamoc Island.

Port Bicobian (17° 17′ N.; 122° 23′ E.), Luzon, is an arm of the sea penetrating 2½ miles to the northward. At the head of the port there is a well-sheltered anchorage in a basin about 600 yards in diameter, having a depth of 10 fathoms, soft, sticky bottom. The plan of the port seems fairly correct, but two shoals near the western bank, half way up the bay, do not appear on the plan. Several large rocks were found near the western side of the entrance, close in shore.

Dilasac Bay (16° 27′ N.; 122° 8′ E.), Luzon, included between Dinapiqui and Tarigtig Points, is 10 miles wide and 7 miles deep. There are two bights in the southwestern part of the bay, and the western one forms a fine harbor which affords excellent anchorage, completely landlocked, in 5 fathoms of water, with soft, sticky bottom. Off the eastern entrance point of this bight there are detached rocks extending nearly ¼ mile northeastward. About 1 mile southwest from the eastern entrance point there is a dangerous reef, awash at low water; it is about 600 yards in extent northwest and southeast and about 350 yards in width. The narrow channel to the eastward of it is less than ¼ mile wide and has 4 fathoms of water; the passage to the westward is wide and clear, and 6 fathoms will be found close to the northwest end of the reef. The 5-fathom anchorage is off the southwest side of the reef, about ¼ mile from it. The entrance to the anchorage presents no difficulty. A vessel should be steered midway between the two shores and hauled gradually to the southward to clear the shoal on the eastern side of the port. The rise and fall of the tide in this bight is about 8 feet. The eastern bight of Dilasac Bay is open to the northeast monsoons and does not afford shelter.

Casiguran Bay (16° 5′ N.; 121° 53′ E.), Luzon, is a long arm of the sea extending for 15 miles in a northeast direction, terminating in a landlocked basin, 4 miles long in a northeast and southwest direction and 2½ miles wide, which can be entered by a deep clear channel, three-fourths of a mile wide. The eastern shore of the bay is clean and steep-to and can be approached to one-fourth of a mile. The depth in the middle of the outer part of the bay generally exceeds 35 fathoms. The western shore is much shoaler than the eastern, and in many places an anchorage can be had in 20 fathoms, as the water shoals rapidly in many places.

Baler Bay (15° 50′ N.; 121° 35′ E.), Luzon, situated to the southward and westward of San Ildefonso Peninsula, can be recognized by the highland all around the bay and up the coast as far as Casiguran Bay. Encanto Point, at the eastern entrance to the bay, has several islets and rocks that dry at low water extending off it for about 1 mile. Baler Bay may be entered on a S. 80° W. course, keeping 1½ miles from the south shore, the water gradually shoaling from 18 fathoms off the point of Los Confites Reef, to 4 fathoms off the reef making out from the point to the eastward of the mouth of the Baler River. There is anchorage in from 8 to 10 fathoms, with river mouth open and bearing about south. A green hill lies a little to westward of the anchorage. The town of Baler is back from the shore, and only the church spire can be seen when entering the anchorage.

Port Camagon (14° 8′ N.; 121° 55′ E.), probably identical with Port Barcelona, on the southwest side of Alabat Island and about 8 miles northeast of Atimonan, is quite small, having accommodations for three or four vessels of about 500 tons each. It affords excellent shelter during stormy weather from the northward and eastward and is reported to be a good typhoon anchorage. It is formed by a small bight in the coast about 1 mile across between the east and west points. Long reefs of sand and stones extend off these points; about midway between these reefs and about one-half mile from shore there is a reef of sand and rocks (either detached or connected with the reef off the south point) visible at low water. The shore of the port is low with an extensive sand beach. The town of Camagon is on the eastern side of the port. There is a small stream on the north side of the port whose fresh water can be obtained; boats can easily enter at high water. The rise and fall is about 4½ feet. The most conspicuous building in the town, and the first seen when approaching the port, is the convent, a large wooden building painted white, with a galvanized iron roof. With the convent bearing N. 78° E. a vessel can easily feel her way with the lead to an anchorage, the depth gradually decreasing from 18 fathoms south of the west point to 3 fathoms about one-fourth mile from the shore. The above description agrees with the plan of Barcelona, and they are probably identical.

San Miguel Bay (13° 42′ N.; 123° 10′ E.), Luzon, is a large bay 12 miles wide and 20 miles deep, surrounded by high mountains and capable of harboring in safety vessels of any draft. When entering from the eastward care must be taken to avoid the reefs off Pinitan Point and Siruma Island. The reef off the west end of the latter extends to 1⅓ miles distance, and at its end there is a black rock plainly visible at low water. Depths of 9 fathoms were found 50 feet to the westward of this rock and 7 fathoms to the eastward, then gradually shoaling to 2 fathoms and less at a distance of one-half mile from Siruma Island. Another shoal and reef make out in a N. 35° E. direction from the northeast end of the island for a distance of 1½ miles, breakers being plainly visible for a distance of several miles. Depths of 6 and 7 fathoms will be found in the middle of the bay, decreasing gradually toward the shore. The southern part of the bay is shoal. The small town of Cabusao is on the left bank at the mouth of the Bicol River. Cabalanga River is 6 miles to the eastward, and the town of the same name is built a little way up the stream.

Pitogo Bay (13° 50′ N.; 123° 56′ E.), Luzon. In making for this anchorage, which bears about west from the northern Catanaguan Island, a vessel should stand into the bight and steer a course parallel to the northern shore at about 200 yards distance, until the shore trends northerly, forming the northern bight, then head for light gray stones in the bank on the western shore just to the right of the western small bight, and anchorage may be taken up in 10½ fathoms, muddy bottom, the southern entrance point bearing S. 89½° E. and the north tangent of the northern Catanaguan Island N. 70½° E. In typhoon weather small vessels should stand up the northern bight, planting anchors off each quarter, while bow anchor is let go well to the northward. This is necessary, as the bight is not wide enough to permit swinging. The main bight is open between N. 51° E. and N. 79° E., admitting considerable sea. Very small vessels can anchor behind the reef in the western bight, but the channel around the reef is narrow and rocky, requiring great care.

Atalayan Island (13° 34′ N.; 123° 35′ E.) is a small, high island situated about 1 mile to the eastward of Sagnay Point, between which and the island is the best typhoon anchorage in the gulf.

The island is steep on its eastern and southern shores and can be approached to 400 feet in deep water. In making for this anchorage vessels should steer west for the highest part of the island, and when 400 yards from it pass around the southern end of the island and stand into the bight on the Luzon shore. Anchorage in 10 fathoms, soft bottom, will be found one-third mile from the beach, the bearings being: north point of mainland Luzon, N. 12° E.; south point of mainland Luzon, N. 82° E.; north point Atalayan Island, N. 4° E.; south point Atalayan Island, N. 65° E. The opening between the northern end of Atalayan Island and Sagnay Point is fairly protected by outlying reefs, especially from the Luzon side, while the anchorage remains open to the southward of Atalayan Island between the bearings of N. 60° E. and N. 82° E. The water in the bight is very deep, especially on the north shore, where 25 fathoms, mud bottom, was found, the vessel being within 200 feet of the beach. The anchorage already given seems the only feasible one in the bight.

Port Sula (13° 15′ N.; 123° 52′ E.), formed by a slight enlargement of the southern part of the channel which separates Cacraray Island from Luzon, is well sheltered and has good holding ground, and is used as a harbor of refuge for moderate-sized vessels. It is about one-fourth mile wide at the entrance and carries that width for three-fourths mile, when it narrows and shoals, rendering it unfit for navigation except by very small craft. The depth at the entrance is 14 fathoms, decreasing gradually to 7 fathoms about three-fourths mile from the entrance. The anchorage space is much reduced by reefs which make out from both sides of the port, the width between the reefs being only from 200 to 300 yards. A vessel should keep midway between points in entering. There is a stream with good fresh water in the northeast part of Port Sula.

Port Palapag (12° 42′ N.; 124° 57′ E.), formed by the channel between Batag and Cahayagan and Laguan Islands, is about 7 miles long and 1 mile wide. Part of it is sheltered from all winds and has a depth of from 5 to 10 fathoms. The northern entrance is preferable, having a navigable width of about one-half mile. Vessels entering should keep on the western side of mid-channel, as the reefs from Batag extend farther than those from Cahayagan. A good anchorage may be had in Port Palapag in heavy weather. Four fathoms may be carried through the narrow passage south of Cahayagan Island, but it is too narrow to be navigated by vessels of any size. Coming from the westward keep toward the southern shore when passing the northern point at the entrance to the channel, then starboard the helm to clear rocky patches. A good anchorage is just to southward and westward of southeast point of Cahayagan Island in 5 fathoms of water, but there is not much swinging room for large vessels, 2,000 tons and above, which should anchor southeast of Cahayagan Island. South of Batag Island there are many coral patches. Five fathoms of water may be carried by keeping one-fourth mile from the northern shore, but north of the center of the southern passage there is a coral patch about 800 yards from Batag Island, with 5 feet of water on it. Except in the early morning, and when the sun gets down in the evening, it shows as a dark red patch. Toward the Laguan side there are patches of coral everywhere not shown on the chart.

Borongan (11° 42′ N.; 125° 25′ E.), Samar, is situated about 6 miles southward from Port Libas and is the most important place on the east coast of Samar. The town stands at the head of the bay, which is 1 mile wide and about 3 miles deep. The Burichan, a small river, empties into the bay to the north of the town. The entrance of the bay is between the islands of Andis and Dibinubo, both moderately high and wooded. Andis Island is connected by a reef with Anitaguipan Point, to the northward, and there are reefs and islets between Dibinubo Island and the point of the coast south of Borongan. There is a small, steep, rocky shoal on which the sea breaks slightly in moderate weather, situated in the middle of the north side of the bay, with the south point of Andis Island bearing N. 70° E. Andis Island has a prominent projecting bluff on its northeastern side. This island is thickly populated.

Matarinao Bay (11° 15′ N.; 125° 33′ E.), Samar. About 11 miles to the southward of Lanang is an extensive but little-known bay, 9 miles wide and 7 miles deep, filled with islets and reefs, which will undoubtedly offer good refuge when it becomes better known.

Pambujan (11° 17′ N.; 125° 30′ E.), situated on the western side of Matarinao Bay, is reported to be a good typhoon anchorage. The town is close to the shore, and the anchorage is directly off the town. To enter, the reefs off Matarinao Point should be given a berth of 1 mile.

The opening between two islands, which are low and covered with mangroves, will be made out ahead by a vessel standing in from eastward. Reefs extend off here 800 to 1,000 yards. They should be left 400 yards to starboard. Enter on a mid-channel course, steering about S. 60° W. The reefs off Matarinao Point extend to the westward and surround a round-topped, wooded island that will be seen on the port bow, inside the bay. Between these reefs and those off the mangrove island the width is about 700 yards; the reefs on both sides are clearly defined, and there is more than 10 fathoms of water within 200 yards of them, and no obstructions in the channel. The south point of the low mangrove island should be rounded 300 or 400 yards off, leaving it on the starboard hand, and anchorage taken up when the south point of the island and Matarinao Point are in line. There are some fish weirs off this point of the island, and there is 5 fathoms of water 150 yards from them. Small craft may go farther inside of the island, keeping 150 yards from it. Large vessels may anchor in 9 fathoms on a line between the town and the small round-topped islet previously mentioned. Mud flats make off from the town 800 yards, having 6 feet of water at the outer edge. The southern part of the bay and point to the southward of town have coral patches everywhere. The safe water is to the northward near the mangrove island.

Quinapuntan River Mouth (11° 7′ N.; 125° 31′ E.), Samar.—There is a small bay immediately south of the mouth of this river, nearly encircled by a group of islands, apparently affording protected anchorage in 11 to 13 fathoms. The U. S. S. *Isla de Luzon* entered this bay by a channel in which no soundings less than 5 fathoms were found. The reef around Higoso Point was left at a distance of 600 yards at the eastern end of the middle or most eastern of the islands about the little bay and was steered for on a bearing N. 6° E. The shoal extending to the northward and eastward of this middle island is a mottled brown, covered by 2 feet of water, and steep-to. On approaching this island the course was changed to N. 79° W., and nothing less than 13 fathoms was found in the channel between the middle island and the shoal to the southward of it, this channel leading to the anchorage. Quinapuntan town is several miles up the river from its mouth.

Iloilo (10° 42′ N.; 122° 35′ E.), Island of Panay.—The best anchorage is off the entrance to the river, with the north end of the fort spit bearing nothing northward of west. Abreast of the fort the eddies are strong and irregular on the flood. Vessels drawing 13 feet can cross the bar and proceed 1 mile up to the town of Iloilo. The services of a pilot are necessary, as the currents are strong and the channel is crooked.

Mansalay Bay (12° 31′ N.; 121° 26′ E.), Island of Mindoro, is small but well sheltered, with good holding ground. Vessels of all sizes can anchor in it, sheltered from all winds except from the southeast. The best anchorage in the northeast monsoon is in the north of the bay in 7 fathoms, mud, 400 to 600 yards from the shore. The town of Mansalay is very small. Water can be had from a rivulet, but with difficulty, as a boat can not enter it.

Port Loog (12° 14′ N.; 121° 58′ E.), is the only shelter on the west coast of Tablas during the southwest monsoon. The port is about 4 miles in extent north and south and 3 miles east and west. The shores are steep, and the depth of water is from 9 to 20 fathoms, mud. The entrance points are more than a mile apart, but the channel is reduced in width to half a mile by a reef which projects to a distance of ⅜ mile from the northern point. Within and before the mouth of the port, about 1,300 yards ENE. of the southern entrance point, there is a shoal rock 800 yards long northeast and southwest and 400 yards wide, steep-to, with depths of 5½ to 9 fathoms on the south side. The charts show a beacon on the middle of this shoal. The town of Loog is on the north shore.

South Bais Bay (9° 36′ N.; 123° 7′ E.), situated between South Bais Island and Negros, offers well sheltered anchorage protected from all winds. Canamay Point, on the south side of the entrance, is surrounded by a narrow reef which extends about ¼ mile to the northward. The northern entrance point is clear on the southern side, but has a reef extending to ½ mile in a S. 72° E. direction. There is a bank which dries at low water, the west end of which is ½ mile S. 65° W. from Arboles Point, the second point on the north side of the entrance, and on the end of the bank are the Pampanga Rocks. To enter, bring Arboles Point to bear N. 66° W. and steer for it, giving the outer north entrance point a berth of about 400 yards, and when the latter point bears N. 65° E., starboard and bring it astern and anchor when the wharf at North Point is in line with Pampanga Rocks bearing N. 23° W., in about 6 fathoms of water, mud. Small vessels can round the Pampanga Rocks at a distance of 200 yards, bring the wharf at North Point to bear N. 23° W., and anchor according to draft. The bottom shoals gradually, and 12 feet will be found more than ½ mile to the northward of Pampanga Rocks.

Port Bugut, or **Carmen** (10° 34′ N.; 124° 0′ E.), Island of Cebu, is a small nook situated 3 miles N. 20° W. of Catadman Point, sheltered by the low Islet Pupu. The eastern side of this islet is foul, and there is no passage between the northern side and the shore. The channel leading to the port is on the south side of the islet and is reduced by the shoals on both sides to a width of 200 yards; these shoals wash at low water and are marked by bushes. Within the port the depth is 4½ fathoms, decreasing toward the beach, which is low and covered by mangroves. In December, 1879, two Spanish gunboats rode out a typhoon in this port.

Cebu Harbor (10° 17′ N.; 123° 54′ E.) is formed by the channel which separates Mactan and Cebu Islands. It is very narrow, but comparatively straight and well buoyed. The navigable channel is 220 yards wide in its narrowest part and about 600 yards wide before the town of Cebu.

In case the buoys are gone or out of position the tide rips on the edges of the shoals and the color of the water will indicate the passage.

Port Nasipit (8° 57′ N.; 125° 13′ E.), Mindanao, is an excellent harbor of refuge. The outer harbor is protected except from the northward and has anchorage space ½ mile wide, with a depth of 8 fathoms in the center. The inner harbor is perfectly protected and can accommodate moderate-sized vessels. In passing through the entrance to the outer harbor a mid-channel course should be held to avoid the reef making out on either side, steering for the western tangent of the high lump between the two harbors on a S. 17° W. course. In passing through the channel to the inner harbor vessels should keep near the low point on the western side, as the bank here is sheer. The bottom is uniform and composed of soft mud. The depth in the inner harbor is 5 and 6 fathoms.

Cagayan Anchorage (8° 30′ N.; 124° 41′ E.), Mindanao. There is good anchorage with the dock bearing N. 30° W. in 28 or 30 fathoms. In approaching this anchorage do not bring the town of Gusan, on the south shore, to bear east of south until the dock bears S. 68° W., when it may be steered for. The cable from Iligan lands on the north side of Macabalan Point and is laid from there N. 3° W. 1 mile.

Opol Bay (8° 33′ N.; 124° 35′ E.) lies 5 miles to the westward of the mouth of Cagayan River. There is anchorage in front of the town in 12 fathoms, near a sand bank. A steep reef fringes the coast to 200 yards near Opol and extends out to ¾ mile to the northward from Malugan Point.

Alubijit Anchorage (8° 38′ N.; 124° 28′ E.) is 7 miles northwesterly from Opol and south of Sulanang Point, where the coast forms an elbow fringed by a reef to ¼ mile. The anchorage is northeast of the town in 17 fathoms, to the north of some houses on the beach.

Iligan (8° 15′ N.; 124° 15′ E.), Mindanao.—Iligan is situated in the southeast angle of the bay, on the bank of the river of the same name. The bar of the river is deep, but there are reefs at the entrance. There is a stone pier extending from the northern entrance point of the river. There are reefs on both sides of this pier, which dry at low water. There is a large wooden wharf under construction starting from a position about 1½ miles N. 38° E. from the end of the stone pier. The shore on both sides of this wharf is fringed with reefs that show at low water and extend to ½ mile.

The best anchorage is about 1 mile from shore in 20 fathoms in the following position: Nipa shed near end of new wharf in line with tree on distant mountain S. 35° E.; end of stone pier S. 6° W., and Luinalang Point N. 29° E.

The cables from Cagayan and Misamis land on the north side of the stone pier.

Port Misamis (8° 10′ N.; 123° 45′ E.), Mindanao, is a long, narrow inlet extending in a southwest direction for about 25 miles. It is 9 miles wide at the entrance between Binani and Loculan Points and narrows until, 16 miles from the entrance, it is only 1 mile wide. From this point it spreads out, forming a large shoal basin known as Panguil Bay. The shores of the bay are low and covered with mangroves, but to the northward of Misamis there is an extended sandy shore, and immediately to the southward there is a line of higher coast. There are a number of dangerous reefs and shoals in the approach to the port.

Port Jimenez.—The town of Jimenez (8° 20′ N.; 123° 41′ E.), Mindanao, is situated about 1¼ miles to the northward and westward of Tabu Point and may be recognized by a prominent stone church with a spire, situated well back among the trees. The anchorage behind the reefs is good, but very contracted. A blockhouse and warehouse mark the landing place and the terminus of the road leading to Jimenez, distant about 1 mile. The anchorage recommended is between Madre Reef and the shore, with the large white warehouse bearing S. 80° W., distant 400 yards.

DIRECTIONS.—There are several openings in the reef facing this part of the coast that apparently offer good channels into Port Jimenez, but they have not been surveyed, and the one to the southward is the only one recommended. To enter, bring Jimenez church spire to bear N. 57° W. and steer for it. This course will take a vessel 150 yards to the southward of a reef southeast of Tabu Point, the southwest part of which was marked by a red buoy; as soon as Tabu Point bears N. 30° W. the vessel should be hauled to the northward and Tabu Point passed at a distance of not over 150 or 200 yards to avoid a shoal with 2½ fathoms on it lying east of the point. When Tabu bears west the course should be changed to N. 33° W. for the anchorage. When the reconnaissance was made in 1903 a black buoy was placed off Tabu Point, a red buoy southeast of the point, and another black buoy S. 30° E. 1⅓ miles from the same point. There is another anchorage recommended to the southward of Tabu Point in 6 or 8 fathoms. All the reefs are outlined by breakers if there is any sea. They show a bright yellow in the sunlight and are very definitely marked by the color. If the buoy or marks are gone it is necessary to have a good light in order to enter with safety, unless familiar with the place.

Port Inamucan, situated about 1½ miles to the westward of Polo Point, is the harbor for the town of Langaran (18° 36′ N.; 123° 39′ E.), Mindanao, standing on the coast about 1 mile to the northwest of the port. It is small and affords good protection in southwest weather and fair shelter in northeast weather on account of the reefs extending from both entrance points. The anchorage space is very limited, being less than ¼ mile in diameter.

DIRECTIONS.—To enter, a vessel should head in on a course S. 24° W., halfway between the fish weir on the west side of the entrance and Baubaon Point, the eastern entrance point. When the fish weir is abeam and the buildings on the west side of the port bear S. 76° W. they should be steered for and anchorage taken up about 200 yards from the western shore, which is steep-to, in 6 to 8 fathoms, soft mud bottom.

Murcielagos Bay (8° 39′ N.; 123° 30′ E.), Mindanao.—Between Bombon Point and Silla Point, about 6 miles to the westward, the coast recedes to the southward, forming a large bay about 3 miles deep. It is nearly blocked up with reefs and islets, among which there are narrow channels where a small vessel could find sheltered anchorage. There are no settlements on the bay except the village of Baliangas in the northeast part and Libay in the southwest.

Port Tagaguilong.—The snug little port of Tagaguilong is in the northern part of Dapitan Bay. It is nearly circular in form, ½ mile in diameter, completely shut in, and very convenient; the depth of water is 5½ to 8 fathoms, and good bottom. The entrance passage is 300 yards wide between the reefs and 9 fathoms deep. A narrow, steep reef lines the shores of the port.

Dapitan.—The town (8° 38′ N.; 123° 24′ E.) is situated on the left bank of the river of the same name, about one-half mile back from the beach on the east shore of the bay. None of the forts shown on the chart are visible from the sea, being completely overgrown by trees. A dilapidated brick fountain on the right bank of the river is quite prominent when seen from the sea. Vessels anchor about one-half mile from the shore, and wagons are driven out as far as possible to transfer cargo and passengers to and from the ship's boats. The bar of the river has very little water on it, but small lorchas can enter at high tide. There is a light frame on Tubod Point, but no light is shown from it.

Sindangan Bay (8° 12′ N.; 122° 56′ E.), Mindanao, included between Dauigan and Sindangan Points, is 17 miles wide and 6 miles deep. The shores are very steep. Anchorage may be had south of Dauigan Point in 3 fathoms, and also east of Sindangan Point, very close to the shore, in 11 fathoms. In all other parts of the bay the water is too deep near the shore for anchorage. Point Dauigan or Dawigan is identical with Point Langoyon of the more recent maps of Mindanao.

Port Santa Maria (7° 46′ N.; 122° 5′ E.), Mindanao.—This well-sheltered little port is situated immediately south of Bulangolan Point. It is about one-fourth of a mile wide at the entrance and extends nearly 1 mile to the southeast and contains two basins fit for small vessels. In the middle of the port the depth is 15 fathoms and a little less near the shore. A narrow reef fringes the shore and extends 200 yards from the western shore at the entrance of the western basin. There is also a reef making out to the northward of the point which projects from the south shore and forms the division between the two basins. The extremities of these two reefs are marked by beacons according to the chart, and a fort is shown on the summit of the hill forming the western side of the port. The shores are low and covered with forests. The anchorage area is very small, that in the western basin, off the mole, being only about 300 yards in diameter and in the eastern basin about 700 yards. Water can be obtained from a small stream in the eastern end of the port.

Sibuco Bay (7° 20′ N.; 122° 3′ E.), Mindanao, situated between Bototindoc Point and Buril Point, 6 miles to the southward, penetrates 3 miles to the eastward. It is free from danger, with steep shores, bordered by a long sand beach with a small river at each end where boats can enter and obtain water even at low tide. The depth in the bay is not less than 27 fathoms, except very close to the beach, where 11 fathoms are found. The anchorage is a good one, but a sea sets in with westerly winds. The town is 2 miles inland.

Caldera Point (7° 0′ N.; 121° 56′ E.), Mindanao, is sandy and forms the western side of a large bay. All these points, as well as the coast they define, are clear and steep-to. Caldera Bay and Port lie to the eastward of the point of the same name. There is anchorage in the bay in 7 to 9 fathoms, sand bottom. There is a small inner harbor capable of holding four or five vessels of 6-feet draft. The entrance channel is 70 yards wide and 12 feet deep.

Port Masinloc (6° 58′ N.; 122° 10′ E.) is the name given to the channel between the Saccal group and Mindanao. It is about 6 miles long and three-fourths of a mile wide. Good anchorage may be found anywhere in this strait in 6 to 12 fathoms of water, completely sheltered from wind and sea. Vessels take refuge here during bad weather in the southwest monsoon.

Between the north end of Saccal Island and the mainland there are clusters of shoals which divide the passage into two channels. The northern one is about one-half mile and the southern one-third of a mile wide.

Port Banga (7° 30′ N.; 122° 24′ E.), Mindanao, is situated in the northern part of Tunganan Bay. The entrance is 6½ miles north from the easternmost of the Tigbaon Islands. It is 3 miles northeast and southwest, with a maximum width of 1 mile. An islet with a reef extending one-third of a mile to the southward divides the entrance into two deep channels, each 300 yards wide. In the eastern channel the depth is 13 fathoms, decreasing gradually to 2 fathoms at the head of the bay. Port Banga is a good, roomy, well-sheltered anchorage. There is a small reef, not shown on the chart, extending out from shore on the eastern side of the port toward the small islet near the western shore, but leaving a deep, clear passage between. The anchorage is midway between this reef and the western shore, in 16 to 18 fathoms of water. The reef on the eastern entrance point extends 500 yards to the southwest and about 2 miles to the east-southeast.

Anchorage.—During the northeast monsoon vessels can anchor in the middle of the bay south of Alto de Flechas in 5½ to 9 fathoms. Water can be had at a rivulet 1½ miles eastward of the anchorage. There is also anchorage in the same depth off Flechas Point (7° 22′ N.; 123° 25′ E.), the southwest extremity of the peninsula, but when the monsoon blows freshly a heavy sea sets around the point.

Tucuran (7° 48′ N.; 123° 30′ E.), Mindanao, is situated about 7 miles to the eastward of Tiguma Point. The cables to Malabang and Zamboanga start from the entrance of Tucuran River and are laid S. 9° W. for ¾ mile; this takes them clear of the usual anchorage. Tucuran should be approached with caution, as the water shoals suddenly; but good anchorage may be had in 20 to 15 fathoms, muddy bottom, by standing in with blockhouse near the beach bearing in 1° E. on this blockhouse nearly in range with the west end of the largest nipa house in the village. The sea at the anchorage is much discolored at times by muddy water out of the river near the village. The position of the village seems to be shown 2 miles too far westward, as it is in the bight westward of Caliton Point and at the foot of the hills near by. There is an army post some distance back from the bay on the side of the hill.

Polloc Harbor (7° 24′ N.; 124° 11′ E.), Mindanao, between Tugapangan Point to the northward and Marigabato (Red Rock) Point to the southward, is an excellent harbor, well sheltered, with an easy entrance, but with great depth of water. It is open to the westward, but it is protected from winds from that quarter by Bongo Island. On the north side it contains the bays of Quidancac and Sugut, and on the south side a wider bay, in which are the anchorages of Polloc and Paran-paran. A steep coral reef fringes the shore; on the north side it is very narrow; on the south side it extends 400 to 700 yards from the shore, and south of Sugut Bay it projects nearly 2 miles to the southwest or about 200 yards farther than shown on the charts. The depth at the entrance is over 40 fathoms; within it ranges from 15 to 25 fathoms, and alongside the fringing reef about 5 fathoms. There is a small detached hill at the foot of the bay which serves as a good mark for vessels bound for Paran-paran.

DIRECTIONS.—Vessels bound for Paran-paran should bring the Army post, which is situated on the hill and is very conspicuous, to bear about east and steer for it, thus giving the reef off Sugut Bay more room than would seem necessary according to the chart. Anchorage may be taken up in 15 fathoms, muddy bottom, about one-fourth of a mile westward from the stone pier. The military cable from Malabang lands in a small cove north of the pier.

Polloc is situated on an island of the same name, separated from the mainland by a narrow channel, with only 2 feet in it at low water. At present none of the beacons shown on the chart in this harbor is in place, except the spar buoy consisting of four bamboo poles in 5½ fathoms, marking the southern limit of the anchorage, and the beacon marked "stakes" off the end of the jetty. This latter beacon bears N. 80° E. from the end of the jetty and not as shown on the chart. Larger vessels should anchor in 15 fathoms, with the end of the jetty bearing N. 65° W. and the spar buoy on the edge of the reef bearing south.

Port Lebak (6° 33′ N.; 123° 59′ E.), Mindanao, between Lebak and Nara Points, about 11 miles south of Linao Bay, affords good shelter in all weathers, but a sea sets in with westerly winds. The shores are covered by mangroves and bordered by a reef which extends about 200 yards from them. There is an islet, Tubotubo, situated in the southern part of the port, surrounded by and connected with the shore by a reef. The best anchorage is in 11 to 13 fathoms eastward of Tubotubo Islet and reef. Water can be obtained in the Lebak River, east of the anchorage, and also from the other rivers in the port. The natives are said to be in the habit of using poisoned arrows on the smallest pretext. It is therefore well to be careful and not to trust them too far.

Basianan Bay, situated about 4 miles to the southward of Port Lebak, affords two anchorages. That in the northern part of the bay, east of Basianan Point, affords good shelter for very small craft in all weathers, but it is necessary to secure to the shore, as there is not sufficient room for a vessel to swing. The southern anchorage is at the mouth of a small creek on the northern side of a prominent hill, connected with the mainland only by a low mangrove-covered neck. The anchor can be dropped in 10 to 13 fathoms and the stern secured to the reef. The reef at the point and the neighboring Island of Donanang break the sea, and these anchorages of Basianan are, after Port Lebak, the best shelters which this coast affords in all weathers.

Sarangani Bay (middle of entrance about 5° 48′ N.; 128° 8′ E.) has a width of about 7 miles between Balaluan and Sumban Points. It is reported that this bay seems to be charted 7 miles too far to the southward and eastward. Its sides are very steep, and the water is deep. Anchorage may be formed in the bights of its coast line, but very close in, and with a line out to the shore to prevent the anchor from slipping into deep water. The chart shows a coral reef extending 1 mile out, surrounding Balaluan Point and bordering the western and northern shores of the bay. The military post of Macar stands on the western shore of the bay. There is no suitable anchorage off it, and it is reported that no sounding can be obtained until within 100 yards from the beach, and then 17 fathoms.

Mutul Anchorage is in the northwest angle of the bay, in 15 fathoms, with moorings to the shore. Good water can be obtained from Mutul River.

Matutum Volcano is very high and can be seen from a great distance. It is shown on the Spanish chart as lying N. 19° W. 19 miles from the town of Mutul, but the Derrotero gives the position as N. 4° E., distant 9 miles from Mutul, and other maps give the distance as 12 miles.

Port Patuen (5° 29′ N.; 125° 25′ E.), close to the northern end of the Island of Sarangani (proper), offers sheltered anchorage for small vessels in 8 fathoms; the stern should be secured to the shore. The entrance may be recognized by a cliff of red earth a little to northward of it. The channel is narrowed by reefs on both sides.

Port Tumanao, near the former, situated 1 mile south of Tiain Point, has 25 fathoms at the entrance, diminishing to 9 fathoms in the eastern part of the port. Good anchorage for small vessels may be found in 15 fathoms about one-fourth of a mile from the head of the port.

This place was formerly a Spanish military post. The northern entrance, which is bordered by a reef to one-fourth of a mile may be recognized by a conspicuous white mark in the rocky bluff. Water can be obtained from a small rivulet in the southeast part of the port.

Malipano Anchorage is on the west side of Samal Island, about 7 miles S. 63° E. from Davao. It is very small, the entrance being only about 120 yards wide and difficult. With the sun overhead the reefs show and the entrance can be made out, but at other times a pilot should be taken. This was formerly a Spanish naval station. All that now remains is a dwelling house, stone pier, and evidences of a coal pile. The anchorage is protected from all winds, but is bad, the bottom being stony, with a few spots of shells and coarse sand.

Lavigan Anchorage, situated about 2 miles northward from Cape San Agustin, Mindanao, is small and shoal and fit only for very small craft. It is partly sheltered from northerly and southerly winds by shoals on which the sea breaks. Good water can be obtained from a ravine southward of the anchorage.

Port Malinao, on the east coast of the Island of Dinagat, 13 miles from Desolation Point, the north end of the island, is a narrow little bay 2 miles deep, with 18 to 2½ fathoms of water. The entrance points are bordered by reefs; the one surrounding the north point extends along the coast to the northward for a distance of 4 miles.

Port Gabo, situated at the south end of Dinagat Island, is well sheltered, being protected to the northward by Mount Caballete and to the southward by Mount Lapa on the island south of Dinagat. The port, which is easily made out from seaward, is nearly 1 mile wide at the entrance and has great depth of water. It extends 1¼ miles to the westward and then forms an elbow to the southward, turning into Gabo Channel. Good, protected anchorage may be found in the northern part of the port one-fourth of a mile from the shore, in 12 fathoms. Fresh water can be procured near the anchorage.

Port Sibonga, Island of Dinagat, on the south side of the middle island at the foot of the conical hill, is divided into two narrow arms by an islet united to a point making out from the south side of the middle island, by a reef that borders the shore. The depth of water in the western arm is 9 to 18 fathoms, bottom sand and stones; in the eastern arm it is 4 to 10 fathoms. The latter arm communicates with Port Castilla on the north side of the island by a channel 15 yards wide and 5 feet deep, which forms the separation between the two islands.

Port Castilla, Dinagat, between the reefs on the north side of the middle and eastern islands, is open to the northward by a narrow passage. It is an oval-shaped basin five-eighths of a mile least diameter, with an available anchorage space one-fourth of a mile in diameter and 8 fathoms in depth. The entire shore of the bay is fringed by a reef.

Port Pilar (9° 52′ N.; 126° 4′ E.), on the east coast of Siargao Island, is a small, circular port, about 1,200 yards in diameter, steep-sided, with a large rock on its south side united to the shore by a reef. The anchorage is west of this rock in 8 to 14 fathoms of water.

Dapa Anchorage (9° 44′ N.; 126° 2′ E.), Island of Siargao.—Anchorage for small craft may be found off the town of Dapa in 4 to 5 fathoms. Dapa is a small, unimportant place. No supplies are obtainable here.

Port Cacub, on the southwest coast of Siargao, is only 100 yards wide at the entrance and 3 to 12 fathoms deep. There is anchorage before the entrance in 12 fathoms. The coast between Dapa Channel and Port Cacub is a mass of rock, dry at low water.

Port Sapao, on the northwest coast of Siargao, is formed by an opening in the reef and is of no importance.

Lianga Bay, between Umanun and Banculin Points, is foul, especialy along the northern shore, from which a reef extends for 2 miles, inclosing the Islet Ayninan. There is a point making out from the west side of the bay and about 1 mile east of this point is the Islet of Jobo. Lianga town (8° 31′ N.; 126° 11′ E.) is at the head of the bay. The chart shows a shoal in the fairway, and there are no soundings given. From the position of this shoal as given on the chart Jobo Islet bears N. 8° W., distant 3 miles, and Lianga town S. 78° W., distant 5½ miles. The best anchorage is said to be off the convent, in 15 fathoms. The coast is rocky, and landing after dark is difficult.

Mayo Bay (middle of entrance, 6° 46′ N.; 126° 18′ E.), between Tuguban Point, 8 miles south of Maglubun Point, and Lamigan Point, is a large bay 5 miles wide and of the same depth. It is little known.

Pujada Bay (entrance, 6° 41′ N.; 126° 13′ E.), separated from Mayo Bay by the long Guanguan Peninsula, which terminates in Lamigan Point, 853 feet high, would be the best harbor in Mindanao were it not for its great depth of water. It is about 4 miles wide at the entrance and extends 11 miles in a northwesterly direction. Pujada Island, 558 feet high, divides the entrance into two channels, of which the southern is the safer on account of the reefs on both sides of the northern channel. The reef of the south end of Pujada Island extends over 2 miles to the eastward and ends in a flat-topped rock. The sea always breaks on this reef.

Paluan Bay Anchorage (13° 23′ N.; 120° 57′ E.), Mindoro.—The best anchorage is in the northern part of Paluan Bay in 14 fathoms (to which the water suddenly shoals from 20 fathoms), with the northern black rock at the river mouth bearing east, distant 1½ miles, and about 1 mile from the beach. The bottom here is tenacious black mud. More convenient anchorage may be had with Paluan Church in sight between the black rocks at the river mouth, bearing S. 80° E. in 9 fathoms, mud bottom.

There is fairly protected anchorage for a moderate-sized vessel during the southwest monsoon in Pamatusin Cove, in the western part of the bay.

Mamburao.—The town of Mamburao (13° 15′ N.; 120° 32′ E.), Mindoro, is situated on level ground on the left bank of the river of the same name. It consists of a few nipa houses and the ruins of a church. The roof of the bell tower is all that remains of the church, and, being of galvanized iron, looks like a white triangle when seen from a distance. Good anchorage, sheltered from northerly and easterly winds, may be found off the mouth of the river in 5 fathoms. The river is easily picked up, and the mouth when open bears north. Vessels bound to or from Mamburao should keep the town bearing between N. 23° E. and N. 68° E. to avoid the foul ground off the points to the westward and the Mamburao Reef to the eastward.

Ylin Strait Anchorage (12° 17′ N.; 121° 4′ E.), Mindoro.—Good, protected anchorage may be had in Ylin Strait, north of Caguray Point, in 11 to 14 fathoms, mud bottom, about 250 yards from the beach on the Mindoro side. From this anchorage Manadi Islet will be seen open off the northeast end of Ylin Island and the southeast point of Ylin Island open off Caguray Point. This position is abreast of a remarkable high feathery-topped tree about one-fourth of a mile northward from the mouth of the Caguray River.

Halsey Harbor (11° 44′ N.; 119° 56′ E.) makes into the west coast of Culion about 4 miles from its southern extremity and extends in a northeasterly direction for about 5 miles. Saddle Rock lies about 2 miles N. 80° W. from the north entrance point. It is about one-eighth of a mile long, and when seen from the northward or southward has the appearance of a saddle, with the western part rising to a height of 114 feet and the eastern part to about the same height. It is surrounded by rocks awash which extend out one-half of a mile on its eastern side.

Port Culion (11° 51′ N.; 120° 2′ E.) is a sheltered inlet on the northeast side of Culion Island, in Coron Bay. It is 1,200 yards long, but its available width is contracted to 200 yards by reefs on both sides. The town of Culion, on the north side of the port, is small and contains a church and fort. The trade consists of tobacco, turtle shell, trepang, pearl shell, and birds' nests. There is good, sheltered anchorage south of the mole, but as the space is very confined it is not safe for a vessel 200 feet long without being moored bow and stern. Anchorage can be had also east of the fort in 15 fathoms.

Anchorage.—The best anchorage during the northeast monsoon is off the west end of the Cagayan de Jolo Island (6° 45′ N.; 118° 15′ E.), with Tanjong Tavo Tavo bearing N. 7° W., distant about 1⅓ miles, and a remarkable tree on the southwest point bearing S. 63° E., distant about 1⅓ miles, in 9 to 12 fathoms, sand and coral bottom. During this monsoon a swell occasionally sets round Tanjong Tavo Tavo, causing a rolling motion and interrupting communication with the shore, the sea breaking along the entire edge of the reef. At this season there is also anchorage on the south side of the island off the middle remarkable crater lake in 10 fathoms.

Anchorage may also be found on the north side of the island in 18 fathoms, with Lapunlapun Island bearing N. 58° E. and Ton Kamutayajan S. 13° W. Ton Bulingis, on line with the center of summit of a 926-foot peak, east side of the island, is the range for this anchorage. Temporary anchorage for communicating with the north side of the island may be taken up east of Lapunlapun Island, but it is not good.

Port Isabela (6° 44′ N.; 121° 58′ E.) is situated on the Island of Basilan facing Isabela Channel, which separates Basilan from Malamaui. The roadstead is between Malamaui and Lampinigan Island and offers good anchorage in 6 to 16 fathoms, muddy bottom. Port Isabela is at present a naval station and contains a fort, barracks, hospital, repairing yard with work shops for machinery, and a slipway for hauling out small vessels.

Directions.—Port Isabela can be entered from either direction, but vessels generally take the entrance which will bring the tide against them to avoid turning in the channel. The channel is about 4 miles long, and the least width between the 5-fathom curves in 150 yards. The northern entrance is rendered somewhat difficult by the absence of buoys or beacons. In entering, the only precaution necessary is to avoid a shoal covered by 2 feet least water lying one-fourth of a mile from the Basilan shore, which can be done by rounding the east point off Malamaui not extending out over 250 yards. Inside the channel the chart shows a small shoal of 16 feet 200 yards from the Basilan shore; a rock with 13 feet on it 200 yards from the east side of Kalut Island; near the middle of the channel extending 200 yards from the Basilan side a shelf of coral level with the surface; but nearly everywhere after passing the rock off Kalut Island the Malamaui shore can be passed at a distance of 150 yards. Vessels entering from the westward should give the coast of Malamaui a berth of one-fourth of a mile and pass either north or south of Moro Island, care being taken to avoid the 16-foot patch westward of it.

Jolo Roadstead (6° 5′ N.; 120° 58′ E.), between Daingapic and Belan Points, is open to the northward and westward. The coast is clean and consists of coarse sand, the bottom slopes gently, and the 5-fathom curve is generally 400 yards from the shore. A reef about 300 yards wide that uncovers in parts at low water borders the beach before the town of Jolo, leaving a passage of 1 foot depth to a lagoon that penetrates southward.

Anchorage.—The usual anchorage is northward of the light-house in 12 to 14 fathoms. During the northeast monsoon ships are sometimes obliged to leave Jolo roads and take up an anchorage under the lee of Marongas Island. This is not a good anchorage, as the bank is steep and the tidal currents strong.

Maibun Bay (5° 54′ N.; 121° 0′ E.), Island of Jolo, affords good shelter during the northeast monsoon, but it is liable to a heavy swell during the southwest monsoon, which sets in in June. The bay is 8 miles wide between Catalian Point, the western entrance, and Putic Point, the eastern entrance point and extends 3 miles in a northerly direction. At the head are the river and town of Maibun. The shores of the bay are bordered by a narrow coral reef, and a depth of 5 fathoms will generally be found at 400 yards from the shore. The western shore is wooded, with cleared spaces. The eastern shore is covered by mangroves. The town of Punungan lies not far from Putic Point.

Anchorages.—There is a fair anchorage off the north end of the channel, between Loran and Ubian Islands (5° 9′ N.; 120° 27′ E.) in from 7 to 12 fathoms, sand bottom, and on the bank east of Pandanan Island in from 8 to 10 fathoms, sand bottom. Anchorage may be also had east of Cacataan in 10 fathoms, sand bottom, and on the mid-channel bank between Cacatáan and Bubuan Islands, both to the southwest and north of the rocks awash; at the former anchorage in 7 and at the latter in 8 fathoms, bottom sand and shells.

Port Bongao (5° 1′ N.; 119° 45′ E.) is formed by the Islands Bongao, Sangsanga, and Papahag and would be a fine harbor were it not for the numerous reefs which contract the anchorage space to a basin about 600 yards in diameter, having a depth of about 6 fathoms in the center. The village consists of a few shacks on the north side of the bay. There is at present a military post on the west side of a rocky point making out from the northeast point of Bongao Island from the end of which a reef, partly dry at low water, extends out into the channel. At the extremity of the reef there is a stake on which a red light is shown at night when a steamer is expected. There is a wharf immediately inside of the point that is said to have 18 feet of water at low water at the end. Bongao is of no commercial importance, and no vessels are seen there except an occasional Army transport. None of the beacons shown on the chart exist at the present time, with the exception of the stake previously mentioned. Vessels bound in here generally use the southern channel, pass the stake close-to, and round it sharply if bound to the wharf. The space between the end of the wharf and the reef in the middle of the port is only about 150 yards wide. No water or stores of any kind are obtainable. There is a small supply of coal belonging to the Government. Vessels bound into Port Bongao by the southern entrance should keep Thumb Hill open off the east end of Papahag Island to clear the shoals extending from Martinez Point, and when the middle of the channel between Bongao and Papahag Islands bear N. 44° W. it may be steered for.

In order to facilitate the finding of the description of the various ports of refuge, they are grouped in the two following tables according to increasing latitudes:

PORTS OF REFUGE IN THE FAR EAST, ARRANGED ACCORDING TO INCREASING LATITUDES.

A. PORTS ALONG THE CHINESE COAST.

Name.	North latitude.	Longitude east of Greenwich.	Island or group.	Page.
	° ′	° ′		
Yulikan Bay	18 12	109 33	Hainan	250
Goalong Bay	18 13	109 34	do	250
Backli Bay	19 07	108 39	do	250
Maniu Harbor	19 57	109 52	do	250
Hunghom Bay	20 17	110 23	do	250
Hai-ling-san	21 34	111 47		250
Namo Harbor	21 35	112 34		250
St. Johns Harbor	21 40	112 42	St. Johns Island	250
Deep Bay	22 17.5	114 16		250
Kowloon Bay	22 18.5	114 13		250
Stonecutters Island	22 20	114 8	Stonecutters Island	250
Chingwan Bay	22 22	114 6.5		250
Mirs Bay	22 33.5	114 27		250
Tongku Harbor	22 35	113 55		250
Namoa Island	23 28	116 57	Namoa Island	250
Makung Harbor	23 32	119 33		250
Tongsang Harbor	23 47	116 57		250
Haitan Straits	25 26	119 44		250
Pihquan Harbor	27 10	120 31		250

PORTS OF REFUGE IN THE FAR EAST, ETC.—Continued.

B. PORTS IN THE PHILIPPINE ARCHIPELAGO.

Name.	North latitude.		Longitude east of Greenwich.		Island or group.	Page.
	°	′	°	′		
Port Bongao	5	01	119	45	Tawi Tawi Group	265
Ubian Island Anchorage	5	09	120	27	Ubian Island, Tawi Tawi	265
Port Patucu	5	29	125	25	Mindanao	262
Port Tumanao	(1)		(1)		do	262
Sarangani Bay	5	48	125	8	do	261
Maibun Bay	5	54	121	0	Jolo	265
Jolo Roadstead	6	05	120	58	do	264
Lavigan Anchorage	6	18	126	03	Mindanao, Bay of Davao	262
Basianan Bay	(2)		(2)		Mindanao	261
Port Lebak	6	33	123	59	do	261
Pujada Bay	6	41	126	13	do	263
Port Isabela	6	44	121	58	Basilan	264
Cagayan de Jolo	6	45	118	15	Cagayan de Jolo	264
Mayo Bay	6	46	126	18	Mindanao	263
Malipano Anchorage	6	56	125	42	Mindanao, Bay of Davao	262
Port Masinloc	6	58	122	10	Between Saccal Group and Mindanao.	260
Caldera Point	7	00	121	56	Mindanao	260
Sibuco Bay	7	20	122	03	do	260
Flechas Point	7	22	123	25	do	260
Polloc Harbor	7	24	124	11	do	261
Port Banga	7	30	122	24	do	260
Port Santa Maria	7	46	122	05	do	260
Tucuran	7	48	123	30	do	260
Port Misamis	8	10	123	45	do	258
Sindangan Bay	8	12	122	56	do	260
Iligan	8	15	124	15	do	258
Port Jimenez	8	20	123	41	do	259
Cagayan Anchorage	8	30	124	41	do	258
Lianga Bay	8	31	126	11	do	263
Opol Bay	8	33	124	35	do	258
Port Inamucan	8	36	123	39	do	259
Dapitan	8	38	123	24	do	259
Port Tagaguilong	(1)		(1)		do	259
Alubijit Anchorage	8	38	124	28	do	258
Murcielagos Bay	8	39	123	30	do	259
Port Nasipit	8	57	125	13	do	258
South Bais Bay	9	36	123	07	Between South Bais and Negros.	257
Dapa Anchorage	9	44	126	02	Siargao	263
Port Sibonga	9	51	125	34	Dinagat	262
Port Gabo	9	51	125	40	do	262
Port Castilla	(3)		(3)		do	262
Port Pilar	9	52	126	04	Siargao	262
Port Malinao	10	10	125	40	Dinagat	262
Cebu Harbor	10	17	123	54	Cebu	258
Port Bugut or Carmen	10	34	124	00	do	258
Iloilo	10	42	122	35	Panay	257
Quinapuntan River	11	07	125	31	Samar	257
Tacloban	11	15	124	59	Leyte	254
Matarinao Bay	11	15	125	33	Samar	256
Pambujan	11	17	125	30	do	256
Parasan Harbor	11	42	124	45	Parasan, west coast of Samar	254
Borongan	11	42	125	25	Samar	256
Halsey Harbor	11	44	119	56	Culion	263
Canahauan Islands	11	50	124	41	Near west coast of Samar	253
Port Culion	11	51	120	2	Culion	264
Libucan Daco	11	54	124	38	Near west coast of Samar	253
Port Cataingan	11	58	124	01	Masbate	253
Port Loog	12	14	121	58	Tablas	257
Ylin Strait Anchorage	12	17	121	04	Mindoro	263
Port Palanog	12	22	123	36	Masbate	253
Port Magdalena	12	27	123	32	do	253
Mansalay Bay	12	31	121	26	Mindoro	257
Port Barrera	12	32	123	22	Masbate	252
Busainga	12	38	124	05	Southern Luzon	252

[1] Near preceding.

[2] Four miles south of following.

[3] Northwest of preceding.

PORTS OF REFUGE IN THE FAR EAST, ETC.—Continued.

B. PORTS IN THE PHILIPPINE ARCHIPELAGO—Continued.

Name.	North latitude.		Longitude east of Greenwich.		Island or group.	Page.
	°	'	°	'		
Port Palapag	12	42	124	57	Batac, near north coast of Samar.	256
Port Sorsogon	12	55	123	55	Southern Luzon	252
Port Busin	13	8	122	58	Between Busin and Burias	252
Mamburao	13	15	120	32	Mindoro	263
Port Sula	13	15	123	52	Southern Luzon	256
Paluan Bay	13	23	120	57	Mindoro	263
Port Galera	13	31	120	57	do	252
Port Banalacan	13	32	121	52	Marinduque	252
Atalayan Island	13	34	123	35	Atalayan, near east of Southern Luzon.	255
Port Maricaban	13	41	120	50	Between Caban and Maricaban.	252
San Miguel Bay	13	42	123	10	Southern Luzon	255
Pitogo Bay	13	50	123	56	do	255
Port Camagon	14	08	121	55	Alabat	255
Mariveles	14	26	120	29	Northern Luzon	251
Port Olongapo	14	48	120	16	do	251
Subig Bay	14	53	120	12	do	251
Port Matalvi	15	30	119	56	do	251
Baler Bay	15	50	121	35	do	255
Casiguran Bay	16	05	121	53	do	254
Port Bolinao	16	25	119	55	do	251
Dilasac Bay	16	27	122	08	do	254
Port Bicobian	17	17	122	23	do	254
Port San Vicente	18	30	122	05	do	250

GLOSSARY OF TERMS.

By Robert Brown, S. J.

Afterglow.—The radiance seen in the western sky after sunset.

Anticyclone.—An area of relatively high pressure increasing toward the center, in which the wind blows spirally outward, clockwise in the northern hemisphere and counter clockwise in the southern hemisphere.

Antitrades.—Winds blowing in a direction contrary to the trades.

Atmospheric Perturbations.—(1) A storm of any kind; (2) a storm in which there is no well-defined central calm and in which the wind does not exceed the force 8 and the barometer does not fall greatly.

Axis of a Cyclone.—The axis of the cone around which the spirals of the cyclone revolve.

Backing Wind.—A wind which changes in a direction counter clockwise—that is, from west through south to east.

Beaufort's Scale.—The scale devised by Admiral Sir F. Beaufort for estimating the force of the wind.

Baguio.—The Philippine name for a cyclone.

Barocyclonometer.—An instrument for ascertaining the position, distance, and direction of advance of a cyclone.

Bar of a Cyclone.—The heavy bank of dense black clouds, generally composed of strato-cumuli and nimbi, which drift in the lower parts of the spirals of a cyclone.

Body of a Cyclone.—The whole mass of air influenced by the cyclonic movement.

Burst of the Monsoon.—The sudden change of weather accompanying the setting in of the southwest monsoon.

Calm Center.—The central area of a cyclone. *Absolute:* The inner area, generally small, in which there is no wind. *Relative:* An imperfect calm area surrounding the absolute calm in which there are light, variable winds.

Cloud Names:

- *a.* Separate or globular masses.
- *b.* Forms which are widely extended.

A. *Upper clouds.*—Average altitude, 9,000 meters.

- *a.* (1) Cirrus: Detached clouds, delicate and fibrous looking, taking the form of feathers, generally of a white color.
- *b.* (2) Cirro-stratus or veil cloud: A thin, high, strated sheet cloud.

Cloud Names—Continued.

B. *Intermediate clouds.*—Between 3,000 and 7,000 meters.

- *a.* (3) Cirro-cumulus: Small globular masses or white flakes without shadows.
- (4) Alto-cumulus: Largish globular masses, whitish or grayish, arranged in groups and lines and often so closely packed that their edges appear confused.
- *b.* (5) Alto-stratus: A thick sheet of cloud of gray or bluish color.

C. *Lower clouds.*—2,000 meters.

- *a.* (6) Strato-cumulus: Large globular masses of dark color.
- *b.* (7) Nimbus: Rain cloud; a thick layer of dark clouds without shape and with ragged edges.

D. *Clouds of diurnal ascending currents.*

- (8) Cumulus: Apex, 1,800 meters; base, 1,400 meters. Woolpack clouds: Thick clouds of which the upper surface is dome shaped and exhibits protuberances, while the base is horizontal.
- (9) Cumulo-nimbus: Apex, 3,000 meters; base, 1,400 meters. Thunder clouds; heavy masses of clouds rising in the form of mountains, generally having a screen of fibrous appearance above (false cirrus) and underneath a mass of cloud similar to nimbus.
- (10) Stratus.

Convergence of Cirrus.—The belts of cirrus which cross a portion of the sky in "great circles" and converge toward some point, generally the vortex of the cyclone.

Cloudburst.—Sudden precipitation of a great amount of rain in a short time.

Col.—A neck of low pressure between two anticyclones.

Colla.—(1) The Philippine name for a stationary cyclone which brings with it rain and wind from the third quadrant; (2) a cyclonic storm in which there is no well-defined calm center and in which the wind does not exceed the force 8 and the barometric fall is not great.

Corona.—A series of small, colored rings round the sun and moon caused by refraction through thin clouds. The order of the colors is as in the spectrum, viz, the red outside, the violet inside. When there are two circles the diameter of the outer one is double that of the inner.

Cyclone.—An area of relatively low pressure, decreasing toward the center in which the wind blows spirally inward, counter clockwise in the northern hemisphere and clockwise in the southern, round a comparatively small and centrally situated region known as the vortex.

Doldrums.—The belt of calms near the equator.

Dynamic Cooling.—The cooling produced by the expansion of the air when it passes into a region of lower pressure.

Eye of the Storm.—The vortex or central calm of a cyclone in which absolute calm prevails. In this region the clouds occasionally break up, so that the sun, moon, and stars are sometimes visible on the blue sky; hence, probably, the name.

Fall of Barometer.—(1) *Slow fall:* The fall of a barometer during a cyclone in which the normal daily movement is plainly visible. (2) *The distinct fall:* The fall in which the normal daily movement is almost entirely lost. (3) *The rapid fall:* The fall of the barometer at the entrance into zone C of the cyclone. The daily oscillation disappears completely.

Gale.—Strong wind with a velocity of over 30 miles an hour, or with force 7, according to Beaufort's scale.

Gradient.—The difference of pressure, temperature, or other meteorological elements per units of distance. *Barometric:* The difference of the atmospheric pressure, measured on a line perpendicular to the direction of the isobars; it is measured by hundredths of an inch of barometric difference per one-fourth of an equatorial degree, equal to 15 nautical miles. *Horizontal thermometric:* The difference in temperature measured on a line perpendicular to the direction of the isotherms; measured in Fahrenheit degrees, one-fourth of an equatorial degree. *Vertical thermometric:* The difference in temperature in a vertical direction (for every 100 feet) between the air strata.

Halo.—A luminous circle of light around the sun or the moon caused by the refraction of light passing through ice crystals floating in the air. True halos are large circles of definite and constant diameters 45° and 92°. They are usually whitish; when prismatic colors exist, the red is inside, the violet outside.

Hurricane.—The West India name for a violent cyclonic storm.

Iridescent Clouds.—The under surface of cirrus or cirro-cumulus, illuminated with patches of iridescent colors.

Isobars.—Lines on a chart connecting points of equal atmospheric pressure.

Isonephs.—Lines on charts joining points of equal amount of cloudiness.

Isotherms.—Lines on a chart connecting places of equal temperature.

Lunar Halo. (*See* **Halo.**)

Mackerel Sky.—Cirro-cumulus clouds.

Mares' Tails.—Long, wispy, cirrus clouds.

Mock Suns and Moons.—Bright patches of light seen at the points where the vertical or horizontal bands of light from the sun or moon intersect a halo.

Monsoon.—A wind that blows steadily along the Asiatic coast of the Pacific over an extent of about 40° of latitude in winter from the northeast (the dry monsoon) and in summer more violently from the southwest (the wet monsoon, or, popularly, "the monsoon").

Nephoscope.—An instrument for observing the direction and velocity of clouds.

Pocky Cloud.—The base of a cumulus cloud when it assumes a festooned appearance.

Rain.—*Purely local:* Rain produced by the rapid ascent of small overheated masses of air saturated with vapor which are carried by the wind to regions containing conditions favorable for the condensation and precipitation of the vapor. *Cyclonic:* The rain which usually accompanies cyclones. It is caused by the saturated air which has a centripetal and rapidly ascending movement, moving toward the center or vortex of the cyclone.

Ridge.—A high-pressure area between two contiguous areas of low pressure.

Scud.—Fragments of clouds driven along by storm winds under heavy clouds.

Secondary Cyclones.—A small depression accompanying a larger or primary cyclone. It is always small in size, but not always so in strength.

Soft Place in the Monsoon.—A tract in the north Indian Ocean between the equator and 9° N., and between Ceylon and Socotra, where the monsoon is weaker than elsewhere.

Southerly Bursters.—The strong, cool, rain-bringing south and southwest winds of Australia.

Squall.—A sudden, short storm of gusty wind. *White:* A small whirlwind in the Tropics, coming suddenly with little warning and with no cloud but a small white patch above the storm center.

Swell of a Cyclone.—The swell caused by the cyclonic wave.

Tornado.—Originally a severe squall on the Gold coast. Now generally applied to the severe and destructive whirlwinds in the United States. The tornado usually advances in the form of a funnel created around the axis of a violent ascending vortex of whirling winds.

Track. (*See* **Trajectory.**)

Trade Winds.—Steady winds between latitudes about 28° N. and 28° S., blowing obliquely toward the equator from the northeast and southeast, respectively.

Trajectory.—The path which the vortex of a cyclone follows.

Trough.—The line of lowest barometric reading during the passage of a cyclone, at right angles to its trajectory.

Typhoon.—The name given to the violent cyclonic storms in the Far East.

Veering Wind.—A wind which changes its direction in the same way as the apparent course of the sun—that is, from east by south to west.

Vortex.—The small calm center of a cyclonic storm.

Waterspout.—A whirlwind passing over the sea in which a spout or trunk is formed joining the cloud and sea.

Wave of a Cyclone.—The immense heap of water accumulated in the vortex of a cyclone, which follows the vortex in its movement of translation.

Whirlwind.—A small, local cyclonic whirl in which there is a very strong upward motion of the air.

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